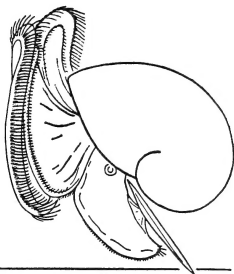


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Volume 11

July 1, 1968 to April 1, 1969

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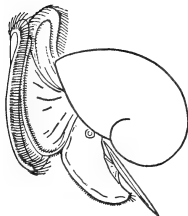
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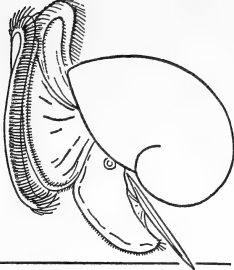
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples, and by increasing indentation.

ORDER, Suborder, DIVISION, Subdivision, SECTION,
SUPERFAMILY, FAMILY, Subfamily, Genus, (Subgenus)
New Taxa

Familial Placement of *Hanetia* JOUSSEAUME, 1880 (Muricidae) and *Solenosteira* DALL, 1890 (Buccinidae)

BY

WILLIAM K. EMERSON

Department of Living Invertebrates
American Museum of Natural History

Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 1; 2 Text figures)

INTRODUCTION

THE GENERIC NAME *Hanetia* was proposed by JOUSSEAUME (1880, p. 335) with *Murex haneti* PETIT (1856, p. 90, pl. 2, figs. 7, 8) the type species by tautonymy and monotypy. Unfortunately, PETIT's taxon was briefly described and poorly illustrated on the basis of specimens stated to have been collected by Hanet Cléry from the coast near Rio de Janeiro, Brazil. As WOODRING (1964, p. 256) has recently stated, despite the questionable identity of PETIT's *Murex haneti* and the lack of confirmation of the Brazilian locality, *Hanetia* JOUSSEAUME, 1880, has been employed in recent years for the distinctive group of New World fossil and living buccinids for which DALL (1890, p. 122) had later proposed the generic name *Solenosteira*, with the Panamic species, *Pyrula anomala* REEVE, 1847, the type species by original designation. This group of cantharid-like gastropods is well represented by numerous named fossils, ranging in age from late Miocene to late Pleistocene, that are known from Florida, Panama, Ecuador, Peru, and the west coast of Colombia, Costa Rica and Mexico. Several Recent species survive in the warm waters of the eastern Pacific, ranging from Mexico to Peru (see KEEN, 1960, pp. 400-402).

Evidence is presented in the present study to demonstrate that *Hanetia* JOUSSEAUME, 1880, is referable to the Muricidae, and therefore, is not a senior synonym of *Solenosteira* DALL, 1890, which is referable to the Buccinidae.

DISCUSSION

Although PETIT's original figures of *Murex haneti*, the type species of *Hanetia*, suggest an inflated, strongly

ribbed specimen of "*Pyrula*" *anomala* REEVE, 1847 (Plate 1, Figures 1-3), similar specimens were not subsequently reported from Brazil, or elsewhere in the western Atlantic. Thus the identity and the western Atlantic occurrence of PETIT's taxon could not be confirmed. MAXWELL SMITH (1939, p. 16; pl. 12, fig. 7), however, illustrated a beach worn Brazilian shell as "*Tritonalia haneti* PETIT," which does not compare favorably with PETIT's illustrations. According to WOODRING (1964, p. 256) this specimen was collected by von Ihering and was deposited in the U. S. National Museum (No. 150767). LANGE DE MORRETES (1949, p. 94) subsequently recorded "*Urosalpinx haneti* (PETIT)" from Rio de Janeiro, citing PETIT's original locality, and he reported this taxon from Santa Catarina Island, Florianopolis, Brazil, citing specimens collected by von Ihering.

At my request, Dr. Bernard Salvat of the Muséum National d'Histoire Naturelle, Paris, kindly provided me with photographs of the type of *Murex haneti* PETIT from the collection of his institution (Plate 1, Figures 4 to 6). The holotype was found to be referable to specimens identified as "*Urosalpinx haneti* PETIT" that were collected by Dr. Bernard Tursch in 3 fathoms off Rio de Janeiro, Brazil (Plate 1, Figures 7, 8) and were deposited without soft parts in the collection of the American Museum. Through the courtesy of Mr. Masao Azuma of Nishinomiya, Japan, a drawing of the radula of a small specimen labeled "*Murex haneti* PETIT" from Governador Island off Rio de Janeiro, Brazil (ex-U. S. N. M. No. 364129) was provided me (Text figure 1). The radula, although from an immature specimen, is that of a muricid, whereas the radula of "*Pyrula*" *anomala* (REEVE, 1847) is that of a buccinid (Text figure 2).

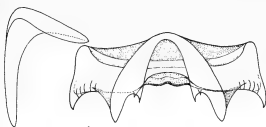


Figure 1

Radular rachidian tooth and lateral teeth of "*Murex*" *haneti* PETIT, 1856, greatly enlarged; from a juvenile specimen collected by Dr. Waldo L. Schmitt at Governador Island, Brazil, ex U. S. N. M. No. 364129 (A. M. N. H. No. 142443)

On the basis of shell morphology, and opercular and radular characters, *Murex haneti* PETIT, 1856, is, therefore, referable to the Muricidae, subfamily Tritonaliinae [=Ocenebrinae]. *Hanetia* JOUSSEAUME, 1880, is available for *Murex haneti* and possibly for other *Urosalpinx*-like species with similar radular and opercular characters that are placed at the present time in *Urosalpinx* STIMPSON, 1865, or in other genera. *Urosalpinx rushii* PILSBRY (1897, p. 297), a taxon described from Maldonado Bay, Uruguay without an illustration, may be a junior synonym of *Murex haneti* PETIT, 1856.

Solenosteira DALL, 1890, thus can be retained, as it is the earliest available name for the *Cantharus*-like Buc-



Figure 2

Radular rachidian tooth and lateral teeth of *Solenosteira anomala* (REEVE, 1847), greatly enlarged; from a specimen collected by Ben and Ruth Purdy at Puerto Peñasco, Sonora, Mexico (A. M. N. H. No. 141801). Drawings courtesy of Mr. Azuma; redrafted by A. D'Attilio

cinidae of the New World that had been erroneously assigned to *Hanetia* JOUSSEAUME, 1880. The generic name *Fusinoesteira* OLSSON (1932, p. 179), type species, by original designation: *Purpura fusiformis* BLAINVILLE, 1832, of the Panamic faunal province, also is available for angulated species of *Solenosteira*, should these prove to be a biologically valid group.

ACKNOWLEDGMENTS

In addition to Dr. Bernard Salvat and Mr. Masao Azuma, I am greatly indebted to the following friends and colleagues for courtesies of various kinds: Mr. Anthony D'Attilio, Mrs. Dorothy Germer, Dr. Miguel A. Klappenbach, Mr. Henry R. Matthews, Mr. William E. Old, Jr., Mr. & Mrs. Ben Purdy, Dr. Joseph Rosewater, Dr. Donald R. Shasky, and Dr. Bernard Tursch.

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Explanation of Plate 1

Figures 1-2, 4-8: "*Murex*" *haneti* PETIT, 1856. Figures 1, 2: copy of PETIT's (1856, pl. 2, figs. 7, 8) original figures; $\times 1$. Figures 4, 5, 6: holotype in Muséum National d'Histoire Naturelle, Paris; photograph through courtesy of Dr. B. Salvat; $\times 1$. Figures

7, 8: mature specimen from 3 fathoms off Rio de Janeiro, Brazil, Dr. B. Tursch coll. (A. M. N. H. No. 129117); $\times 2$. Figure 3: *Solenosteira anomala* (REEVE, 1847), copy of REEVE's (1847, pl. 3, figure 12) original figure of "*Purpura*" *anomala*; $\times 1$



Figure 1



Figure 2



Figure 3



Figure 4

Figure 5

Figure 6

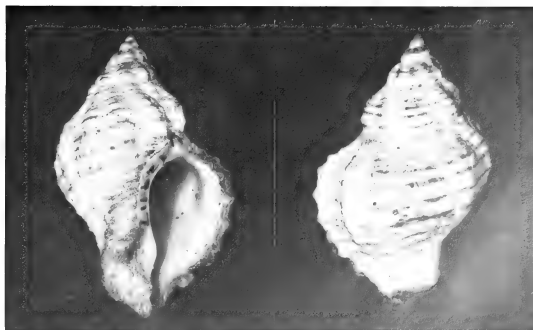


Figure 7

Figure 8

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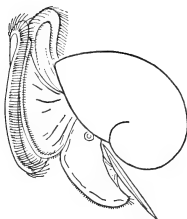
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A Survey of the Littoral Marine Mollusks of the Caribbean Coast of Costa Rica

BY

JOSEPH RICHARD HOUBRICK

Division of Science and Mathematics, St. Leo College, St. Leo, Florida 33574

(1 Text figure; 1 Map)

INTRODUCTION

THE COMPOSITION of the marine molluscan fauna of the western Caribbean is relatively unknown. For a period of six weeks the writer was able to study and collect marine mollusks in two different areas of Limón Province, Costa Rica. The purpose of this work and of the research that followed was to investigate the composition and range of the fauna in order to compile a list of the Recent species, to observe their ecological distribution, and to provide some basis for future study in this little-known section of the Caribbean region.

Although the period was barely sufficient to allow for an exhaustive survey of the mollusks and the entire range of the variety of their habitats, a good portion of the littoral or shallow water fauna is believed to be recorded. However, more complete and sophisticated collecting methods in these areas would undoubtedly extend the list of existing species and provide further pertinent information.

The marine mollusks of the Caribbean coast of Costa Rica have received little or no attention from recent workers. Indeed, the whole of the Caribbean coast of Central America has not received adequate scientific investigation and is poorly known in relation to other areas of the Caribbean Province.

With the prospect of a future sea-level canal being constructed somewhere in the Central American isthmus an investigation of the marine fauna of both the Caribbean and Pacific sides is desirable. A sea-level canal would make possible a limited mixing of the Caribbean and Panamic faunas for the first time since the late Miocene.

The area near Puerto Limón presented the most favorable base for living, transportation facilities, and collecting. Consequently, the major portion of this paper deals with the marine mollusks from this vicinity.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge at this time Dr. Donald R. Moore of the Institute of Marine Science, University of Miami, whose help, interest and suggestions throughout this project have been invaluable. I am also indebted to Drs. William Clench and Kenneth Boss who kindly read the manuscript and offered suggestions. Gratitude is also due to Dr. Axel A. Olsson and Mr. Ted LaRoe who assisted in the identification of some of the fauna. Finally, I am indebted to the Organization for Tropical Studies for the opportunity to collect in some of the areas of Costa Rica and to St. Leo College for both financing the field work and providing leave time for the research involved.

PREVIOUS WORK ON WESTERN CARIBBEAN MOLLUSKS

The literature dealing with the marine mollusks of the Caribbean coast of Central America is rather sparse. This important portion of the Caribbean Province is perhaps the most poorly known by way of actual collection and study. OLSSON & MCGINTY (1958) believed that the principal reason is the scarcity of convenient collecting stations along the Caribbean coast as compared to the abundance and ready accessibility of such grounds on the Pacific side.

The earliest literature on the Recent fauna deals with the mosquito coast of Nicaragua and consists of several short articles and notes published by FLUCK (1900-1901; 1905). The next reference to the area occurs in 1958 with the work of OLSSON & MCGINTY in Panama. This seems to be the only substantial report we have about this area. The paper consists of a faunal list along with the description of some new genera and species. Recently,

BAKUS (1968) has published a comparative study of littoral zonation of the gastropods on the Pacific and Atlantic coasts of Costa Rica in which a brief account of the Limón area is given with a list of the mollusks collected at Portete. With the exception of the above paper and the distributional records listed in Johnsonia, nothing more seems to be recorded of the marine mollusks of the Caribbean coast of Costa Rica.

Two publications dealing with the southwestern Caribbean fauna are those by COOMANS (1958) and REHDER (1962), the former on the gastropods of the Netherlands Antilles and the latter on the Los Roques mollusca.

The fossil mollusca of the western Caribbean have received more attention by workers. GABB (1881) and OLSSON (1922) have reported on the Pliocene and Miocene molluscan faunas of eastern Costa Rica. WOODRING (1957) has investigated the Canal Zone and WEISBORD (1961; 1964) discussed the late Cenozoic mollusca of northern Venezuela and provided an excellent bibliography of the Caribbean fauna.

In conclusion, a survey of the literature reveals that knowledge of the Recent western Caribbean fauna is surprisingly incomplete and spotty. Further research is needed to gain a full picture of this sector of the Caribbean Province.

REGIONAL GEOGRAPHY AND GEOLOGY

The Caribbean slope of Costa Rica is composed of Cenozoic strata which dip away from the central mountains to the sea. The eastern coastline is slightly concave, lacking large bays or inlets. The Atlantic coastal plane occupies nearly one-third of Costa Rica and is almost flat. Offshore, the narrow shelf which is rarely more than 10 miles wide, slopes to a depth of 600 feet.

The climate of this region is tropical with a heavy rainfall. Most of the northern coast of the province of Limón is low and covered with dense forest interlaced with rivers, creeks, brackish estuaries, and swampy areas of *Raffia* palms. The beaches are broad and of a gray volcanic sand. An excellent description of this coastline is given by CARR (1956).

According to OLSSON (1922), there was a complete inter-oceanic connection in this region during the lower Miocene, and nearly all of the Costa Rican isthmus was then beneath the sea. At the close of this epoch, eastern Costa Rica was again emergent for a short period. During the upper Miocene the whole of Costa Rica as well as Panama were in an uplifting process. This elevation destroyed the inter-oceanic connections and culminated in

the early Pliocene. Thus, during the whole of the Tertiary, Costa Rica underwent great changes due to periods of submergence and uplift of its land masses.

In contrast to the northern coastline, the central Limón peninsula is of a coralline limestone formation. OLSSON (1922) and SCHUCHERT (1935) both believed that this outcrop belongs to the Gatun formation. This area is very rich in fossiliferous marls, and GABB (1881; 1881a) described about 70 species of fossil mollusks from the Limón area. OLSSON (*op. cit.*) described 334 species from the Gatun formation.

FAUNAL ORIGINS AND RELATIONSHIPS

The warm tropical waters of the western Caribbean support a molluscan fauna similar to that of the West Indies and the Florida Keys, and are a portion of the zoogeographical area known as the Caribbean Province. WARMKE & ABBOTT (1961) presented a map showing the extent of this province. Conditions are fairly uniform, allowing many species to exist throughout the province, and the molluscan fauna is impressive. ABBOTT (1962) remarked that the larger West Indian islands have over 1200 species of marine mollusks, while the smaller isolated coral islands, poor in food, have only about 350 kinds of mollusks. MOORE (personal communication) found a depauperate fauna in the Albuquerque Cays off Nicaragua. OLSSON & MCGINTY (1958) recorded about 543 species and subspecies from the Panama coast. We report 250 species herein from Costa Rica. The lower numbers of species from the western Caribbean may indicate a poorer fauna or reflect the inadequate work done in this region.

Many species of the Caribbean Province have close affinities to those of the Panamic Province. C. B. ADAMS (1852) was the first to point out the similarities and to draw up a list of analogous species between the two provinces. DALL (1912), in his study of the fossil shells from eastern Panama and Costa Rica, noted that these mollusks were mostly of common Caribbean living forms, but found an interesting admixture of species now living on the Pacific coast. Later, SCHUCHERT (1935) remarked that the Miocene shell faunas of Central America were ancestral to the living ones of the Caribbean and to some in the Pacific. OLSSON (1922) stated that "... thirteen percent of the Gatun fauna is identical or closely related to the recent species the majority of which are found living along the Caribbean coast, certain others only on the Pacific side, and a few common to both." He found 6 species to be specifically identical with forms in the Pacific and 18 others that showed close relationships.

There were probably two natural seaways crossing Central America during the Miocene, the main one across Costa Rica and a second through the Darien of Panama. This permitted free circulation of water between Atlantic and Pacific oceans and it was in these warm seas that the Miocene faunas developed which were ancestral in part to the bulk of modern Caribbean and Panamic faunas. KEEN (1958) observed that the sizeable number of parallel or analogous species on either side testify both to the slowness of change in the isolated stocks and to their past relationships. OLSSON & MCGINTY (1958) and OLSSON (1961) pointed out that the fauna has remained little modified in the Pacific section while the Caribbean has undergone a greater change through a major extinction of many of the older Miocene groups due to the drainage of large tracts of its shallower parts during mid-Pleistocene glaciation in the northern hemisphere. Other groups later invaded this area from the

north and east, and present day Caribbean mollusks, when compared to the rich Miocene fauna, appear to be impoverished.

COLLECTING LOCALITIES

The two areas discussed in this paper are located in the province of Limón, Costa Rica. A map of the area is given in Figure 1. The station most thoroughly worked was that of Portete, a small fishing settlement on the shores of a lagoon located a few miles to the north of Puerto Limón. This is in the central portion of Costa Rica's Caribbean coastline, more precisely at Lat. 10°N, Long. 83°02'W. The whole area consists of a projection of the land into the Caribbean, the coastline being of a coralline limestone formation and somewhat elevated. It is surrounded by moist tropical forest with a network

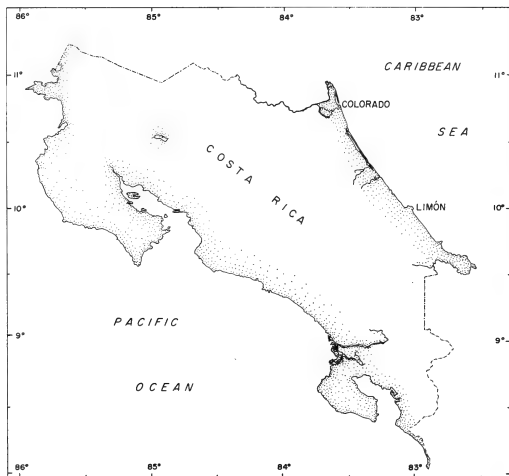


Figure 1

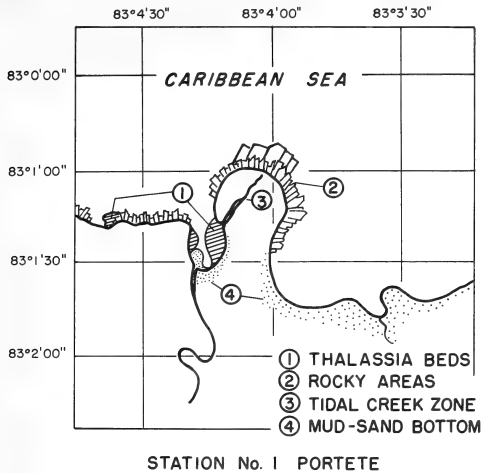


Figure 2

of brackish water lagoons and *Raffia* palm swamps.

Collections and observations at Portete were made during the dry season in March of 1965 for a period of 3 days. The same station was more thoroughly collected for a period of one month during July of 1966, the rainy season.

The second station, Barra del Colorado, will be treated only briefly because it was worked but for a few days. It is located in the northeast portion of Costa Rica at the mouth of the Rio Colorado, Lat. $10^{\circ}40' N$, Long. $83^{\circ}35' W$.

Collecting was confined to the shallow water or littoral fauna in both stations and included beach specimens and drift material. A face mask was used in the shallow areas and on the reefs. Algae were sorted and picked through for the smaller species and drift material was selected and carefully sorted with the aid of a stereo-

microscope for the smaller micromollusks. The *Thalassia* beds and sandy bottoms were sifted with $\frac{1}{4}$ inch mesh strainers. When possible, specimens were obtained from local fishermen. No dredging was undertaken, but this would undoubtedly have increased the faunal list by adding more burrowers and pelecypods.

COLLECTING STATIONS

STATION 1: **PORTETE**

This area (Map, Figure 2) consists primarily of rocky shoreline, surf-washed coves and a somewhat protected lagoon. A small freshwater creek empties into the lagoon and to the north and south of this station there are rivers emptying their muddy contents into the sea. Rainfall

can be heavy during the wet season and is undoubtedly a factor in the salinity of the shallow portions of the coast at this time.

Unfortunately, quantitative data for many of the ecological factors of this area are not known. However, the author's short experience in the area produced some qualitative information which indicates some factors of possible ecological significance and will serve as a basis for future investigation.

No record of the variations of sea temperatures was compiled, but temperatures appear to be typical of the shallow waters of the Caribbean. Values of the oceanic quadrant 10-15° N, 80-85° W have been used. In this quadrant, sea surface temperatures average 27.3° C with a range of mean monthly values of 2° (D. R. Moore, personal communication). Very shallow areas become much warmer during the day due to the effect of the sun. The same is true of the local effects of cooling due to the heavy rains in the wet season. Variations, however, do not appear to be of any significance in the distribution of the common mollusks.

Due to the prevailing trade winds (E - NE) there is a consistent wave action. Periods of severe storms cause wave action to become sufficiently intense to damage the plant and coral growth and to destroy certain ecological environments. In sandy areas the author observed mollusks torn from their substrate and cast up on the beaches by heavy surf action. Wave action seems fairly consistent around this station.

Tides at Portete are diurnal, having a range of 1.2 feet and a mean tide level of 0.3 feet. There are no noticeable strong local currents at this station, but currents related to the wind nearly always flow W - SW.

The ranges of salinity do not seem to be of a magnitude to be detrimental to coral growth and the typical reef-dwelling fauna. The expected forms of mollusks were found except along the margin of the lagoon area into which the freshwater creek emptied. A water sample from this station was taken and analysis of it showed a salinity of 34.083 ppt. Heavy rains can apparently change the salinity in the more shallow portions along the shore and increase the magnitude of the nearby river's discharge.

Turbidity is influenced by the constant wave action. There is a moderate amount of sedimentation contributed by the rivers and creeks near this region. The portion of the lagoon directly affected by the discharge of the creek is devoid of the usual fauna. During periods of heavy rain it appears to discharge considerable quantities of sand and mud, creating a sand bar near its mouth.

Bottom conditions in Portete do not vary greatly. The one exception is the lagoon area where substrate conditions were extensively controlled and modified by flora and fauna and were quite varied.

Substrate conditions at Portete were mostly of 3 types: mud-sand bottom, *Thalassia*-sand flats, and rock-coral bottom. Intermediates and mixtures of these types were present, some areas apparently in transition from one type of bottom to another, but in general the variations of substrates were strikingly defined. For the purpose of study the writer divides the station of Portete into 3 general areas of substrate mentioned above.

A. Mud-Sand Bottom

The mud-sand bottom has a fine film of algal growth covering the sediment and is found only in the center of the lagoon; it extends back toward the shore near the creek. The freshwater creek and its mouth are included in this type of bottom. Few mollusks are found on this substrate, but *Strombus pugilis* is abundant. Water usually covers the mud-sand bottom to a depth of 5 feet or more. No portions of this type bottom seem to be exposed at low tide.

B. *Thalassia*-Sand Bottom

The *Thalassia* flats are all intertidal in nature and prove to be the most rewarding areas in the number of species encountered. The most extensive *Thalassia* beds are confined to the south shores of the lagoon. They consist of beds of *Thalassia* in the deeper portions which slope upward, forming shallow flats of mixed *Thalassia*, *Caulerpa*, *Halimeda* and *Porites*. The water is seldom more than a foot deep here and with low tide there are periods of incomplete exposure. Along the shore this area appears sandy with large rocks and occasional *Thalassia*.

C. Rock and Coral Bottom

Rock bottom environments are the most common and are usually covered with marine algae and corals. They are exposed to the wave action and in some places heavily pounded by surf. In areas of this substrate definite zones characterized by certain flora and fauna are noticed. A zone as defined by RODRIGUEZ (1959) is a "band or region in the shore defined by physical conditions." Zonation was, in many instances, reflected by the types of mollusks found. It is most apparent in areas which are affected by the tides. Substrate, wave action, and the distribution of bottom types are lesser contributing factors in zonation. LEWIS (1960) found that tides, with the varying degrees of exposure they impose, are the primary cause of zonation. This certainly appears to be the case at Portete as zonation is remarkably constant in most rocky areas. Mollusks of these zones show varying degrees of adaptation to tidal factors. That this is due to their larval stages is evident, for the success of these mollusks is not only due to their ability to maintain them-

selves as adults, but should be considered as the sum of successes of the various stages in their life histories.

For purposes of convenience, rocky areas are divided into 5 zones which seemed to predominate at Portete. This partially follows the zonation system of ARNOW, ST. CLAIR, & ARNOW, 1963.

1. Splash Zone – the area above the mean high water levels, including splash pools, areas affected by spray and beach debris.

2. Intertidal Zone – the area between mean high and mean low water levels. An area of loose rocks and stones, sandy-bottom pools and shallow water and frequently completely exposed by tidal action.

3. Rock-Ledge Zone – the subtidal shelf that fringes the coast. It is transversely by cracks filled with holes and niches. Heavy growths of *Padina*, *Hypnea*, and *Acanthopora* and other algae are predominant here. This zone is narrow in most parts of Portete; however, in one area the rocky ledges are quite extensive.

4. Reef Zone – this zone is characterized by coral growth and deeper water. At the edge of this zone and along the outer edge of the rocky shelf zone are heavy growths of *Zoanthus*. Further out *Siderastraea* and *Acropora* coral are common. The hydrocoral *Milleporina* is abundant in this zone. Wave action is generally heavy.

5. Tidal Creek Zone – an unusual cleft cut through the promontory which formed one side of the lagoon. This promontory is heavily pounded by waves on its outer, southern portion. The water thus enters a cleft in the cliff-like sides and forms a salt water creek which eventually enters the lagoon and is subject to tidal action. It is a protected zone, always in the shade, and in some places the creek is almost 15 feet deep. The sea urchin *Diadema* is common on the bottom. Shallow areas are covered with a fine filamentous green alga.

STATION 2: BARRA DEL COLORADO

An area of wide sandy beaches bisected by the estuary of the muddy Rio Colorado, the Barra del Colorado is bordered by wet, tropical rain forest. The beaches are broad and slope gently into the turbid sea. This area is quite similar to that of Tortuguero described by CARR (1956).

No ecological data were recorded, but substrate conditions along the beaches are of the sand-bottom type. No collecting was done in the estuarine areas, but KELSO (1965) found *Polymesoda triangula*, *Mytilopsis zeteki*,

and *Neritina reclinata* to be common in the Tortuguero estuary further south.

This station afforded a number of species and habitat records of mollusks not encountered at Portete.

SUMMARY OF SURVEY AND CONCLUSIONS

A checklist of the species collected in Limón Province whose presence in the Western Caribbean was previously unrecorded in the literature follows:

Arene tricarinata (STEARNES, 1872)
Astraea tuber (LINNAEUS, 1758)
Tegula viridula (GMELIN, 1791)
Puperita tristis (ORBIGNY, 1842)
Parviturbo interruptus (C. B. ADAMS, 1850)
Solariorbis infracarinata GABB, 1881
Heliacus bisulcatus ORBIGNY, 1845
Heliacus infundibuliformis (GMELIN, 1791)
Petalonchus irregularis (ORBIGNY, 1842)
Caecum jucundum FOLIN, 1867
Caecum ryssotium FOLIN, 1867
Caecum cycloferum FOLIN, 1867
Cerithium auricoma SCHWENGEL, 1940
Cerithiopsis pupa DALL & SIMPSON, 1901
Cerithiopsis latum (C. B. ADAMS, 1850)
Cerithiopsis bicolor (C. B. ADAMS, 1845)
Triphora nigrocincta (C. B. ADAMS, 1839)
Triphora pulchellum (C. B. ADAMS, 1850)
Balcis intermedia CANTRINE, 1835
Balcis conoidea KURTZ & SIMPSON, 1851
Eulima auricincta ABBOTT, 1958
Stilifer subulatus BRODERIP & SOWERBY
Risomurex roseus REEVE, 1856
Anachis pulchella SOWERBY, 1844
Bailya parva (C. B. ADAMS, 1850)
Colubraria lanceolata MENKE, 1828
Nassarius nanus USTICKE, 1959
Pusia gemmata (SOWERBY, 1874)
Marginella denticulata CONRAD, 1830
Bullata ovuliformis (ORBIGNY, 1842)
Hyalina tenuilabra TOMLIN, 1917
Crassispira fuscescens (REEVE, 1843)
Leptadrillia splendida BARTSCH, 1934
Mangelia fusca (C. B. ADAMS, 1845)
Pyrogocythara coxi FARGO, 1953
Retusa candei ORBIGNY, 1841
Aplysia brasiliana RANG, 1828
Aplysia dactylomela RANG, 1828
Cingulina babylonica (C. B. ADAMS, 1845)
Miralda havanensis PILSBRY & AGUAYO

Lobiger souverbii FISCHER, 1856
Tralia ovula (BRUGUIÈRE, 1789)
Arca imbricata BRUGUIÈRE, 1789
Pteria colymbus RÖDING, 1798
Crassinella martinicensis (ORBIGNY, 1842)
Condylocardia bernardi DALL, 1903
Mytilopsis domingensis (RECLUZ, 1852)
Diplodonta notata DALL & SIMPSON, 1901
Codakia costata ORBIGNY, 1842
Acanthochitona rhodeus PILSBRY, 1893
Octopus vulgaris LAMARCK, 1798

Of the Recent mollusks found in eastern Costa Rica, a total of nearly 250 species were collected consisting of 181 species of gastropods, 35 pelecypods, 3 scaphopods, 8 chitons, and 2 cephalopods. Table 1 illustrates their composition.

Table 1
Composition of Molluscan Fauna

		Fam.	Genera	Spec.
GASTROPODA	Prosobranchia	43	88	161
	Opisthobranchia	9	12	16
	Pulmonata	1	3	3
PELECYPODA		19	30	35
AMPHINEURA		3	5	8
SCAPHOPODA		2	2	2
CEPHALOPODA		2	2	2

Twelve families are represented by only one species. The families best represented are the Vitrinellidae with 8 genera and the Cerithiidae with 5. The best represented genera are *Rissoina* with 9 species, *Caecum* and *Cerithiopsis* with 6 species each, and *Nerita*, *Epitonium*, and *Trifora*, each represented by 4 species. Sixteen species of Opisthobranchs remained unidentified. Thirty-five species of bivalves were collected of which the largest shares were of the families Arcidae and Tellinidae.

Table 2
Ecological Distribution
of Limón Province Marine Mollusks

	P	G	A	S*
Sand bottom species	11	0	0	3
Mud-sand bottom species	3	3	0	0
<i>Thalassia</i> -sand bottom species	7	38	0	0
Rock-coral bottom species	8	56	7	0

* P = Pelecypoda; G = Gastropoda; A = Amphineura
 S = Scaphopoda

A summary of the general ecological distribution of mollusks collected alive follows in Table 2.

The mollusks collected in this survey have been deposited in the following places: Division of Mollusks, U.S. National Museum; Museum of Comparative Zoology, Harvard University; Museum of the Institute of Marine Science, University of Miami; and in the writer's collection.

SYSTEMATICS

The following systematic listing includes all identified mollusks collected by the author in Limón Province, Costa Rica. Some unidentified opisthobranchs and many micro-mollusks have been omitted from the list. Although nearly 210 species were determined, this in no way implies a complete survey.

In this checklist an attempt is made to record the general distribution of each species throughout the Caribbean Province. The stations and ecological areas where the species were collected then follows, together with additional information of interest. Many species were not found alive and are indicated as beach drift or beach shells.

The classification used in this paper is based upon that of WARMKE & ABBOTT, 1961. The general geographical ranges of mollusks were taken principally from the monographs in Johnsonia, from publications by WARMKE & ABBOTT (1961) and ABBOTT (1954; 1958).

Stations, areas and zones appear after the general range information and are assigned symbols as follows:

P = Portete

- m = mud-sand bottom
- t = *Thalassia*-sand bottom
- r = rock-coral bottom
- 1 = splash zone
- 2 = intertidal zone
- 3 = rockledge zone
- 4 = reef zone
- 5 = tidal creek zone

B = Barra del Colorado

The terms "abundant," "common," etc. indicate the relative occurrence of the species:

- abundant = 100 or more
- common = 15 to 100
- uncommon = 6 to 15
- rare = 5 or fewer

Species with doubtful determination are indicated by a question mark in parenthesis: (?).

GASTROPODA

SCISSURELLIDAE

Scissurella ORBIGNY, 1823

Scissurella sp., P, beach drift. Rare.

FISSURELLIDAE

Hemitoma SWAINSON, 1840

Hemitoma octoradiata (GMELIN, 1791). Range: south Florida and the Caribbean to Brazil. P, r, 2. Found during March in holes and pits on rocks. Uncommon.

Diodora GRAY, 1821

Diodora listeri (ORBIGNY, 1853). Range: southeast Florida and the southeast Caribbean. P, r, 2, 3. Uncommon on rocks.

Diodora arcuata (SOWERBY, 1862). Range: Florida, the Bahamas and the Caribbean. P, t. Uncommon under stones and dead *Porites* coral. Common in beach drift.

Fissurella BRUGUIÈRE, 1798

Fissurella nodosa (BORN, 1778). Range: lower Florida Keys, southern Mexico and the Caribbean. P, r, 3. Commonly covered with calcareous algae. Common.

Fissurella angusta (GMELIN, 1791). Range: the lower Florida Keys, the Bahamas, British Guiana and the east coast of Central America. P, r, 2, 3. Found living in depressions on rocks and exposed flats. Common.

Fissurella barbadensis (GMELIN, 1791). Range: southeast Florida, Bermuda, West Indies, and the Caribbean coast of Central America. P, r, 2, 3. Common on rocks and ledges.

ACMAEIDAE

Acmaea ESCHSCHOLTZ, 1830

Acmaea antillarum (SOWERBY, 1831). Range: south half of Florida to the West Indies and the Caribbean. P, r, 2, 3. Found in cup-like depressions on rocks and ledges exposed to heavy surf. Common.

TROCHIDAE

Cittarium PHILIPPI, 1847

Cittarium pica (LINNAEUS, 1758). Range: Bahamas to the West Indies and eastern Central America; north coast of South America. P, r, 3. Commonly found adhering to alga-covered rocks in surf-pounded places; younger specimens were common in the intertidal zone during the month of March, but were absent in the summer.

Tegula LESSON, 1832

Tegula fasciata (BORN, 1778). Range: southeastern Florida and the Caribbean. P, t. Found commonly on *Thalassia* blades.

Tegula excavata (LAMARCK, 1822). Range: Caribbean. P, r, 2. Found only during March under rocks or in sheltered places. Common.

Tegula viridula (GMELIN, 1791). Range: Central America and the northern coast of South America to Brazil. P, t. Found in *Thalassia* beds. Uncommon.

Parviturbo PILSBRY & MCGINTY, 1945

Parviturbo sp. P. Beach drift. Common.

TURBINIDAE

Arene H. & A. ADAMS, 1857

Arene tricarinata (STEARNS, 1872). Range: southeast U. S. to the West Indies and eastern Central America. P, t. Uncommon. Common in beach drift.

Astraea RÖDING, 1798

Astraea caelata (GMELIN, 1791). Range: southeast Florida, the West Indies and the Caribbean. P, r. Shells only. FLUCK, 1905, found it abundant in Nicaragua.

Astraea tuber (LINNAEUS, 1758). Range: southeast Florida, the West Indies and the Caribbean. P, r. One dead specimen.

PHASIANELLIDAE

Tricolia RISSO, 1826

Tricolia affinis cruenta ROBERTSON, 1958. Range: Western Gulf of Mexico and the Caribbean to Brazil. P, t. Common; abundant in beach drift.

NERITIDAE

Nerita LINNAEUS, 1758

Nerita peloronta LINNAEUS, 1758. Range: eastern Florida, Bermuda and the West Indies to Trinidad, and also eastern Central America. P, r, 1. Found only during March. Uncommon on large rocks.

Nerita versicolor GMELIN, 1791. Range: Florida to Texas, Bermuda and the Caribbean to Brazil. P, r, 2. Abundant on wet rocks in shaded areas.

Nerita fulgurans GMELIN, 1791. Range: eastern coast of Florida, Bermuda, the Caribbean and Brazil. P, r, 2. Common under rocks in sheltered places. RUSSELL, 1941, stated that this species is found in waters of lower salinity but this writer found it commonly distributed along the rocky shores of the Limón peninsula.

Puperita GRAY, 1857

Puperita tristis (ORBIGNY, 1842). Range: Antilles and eastern Central America. P, t. Abundant only in lagoons on stones, dead coral, and debris.

Neritina LAMARCK, 1816

Neritina virginea (LINNAEUS, 1758). Range: Florida to Texas, Bermuda and the Caribbean to Brazil. P, m. Found only near mouth of fresh water creek. Few live specimens taken. Common in beach drift.

Neritina meleagris LAMARCK, 1822. Range: British Honduras to Columbia and the Antilles to Brazil. P, t. Found on rocks and debris with *Puperita tristis*. Common.

Neritina piratica RUSSELL, 1940. Range: Central America, the Antilles, the north coast of South America to Brazil. P, m. Common in freshwater creek on submerged logs and leaves. Intergrades in color pattern ranged from typical *N. piratica* markings to *N. reclinata* and *N. zebra* types, but RUSSELL (1941) claimed there is no intergrading of species. FLUCK (1905) found this species to be common in the lagoons and channels peculiar to the mosquito coast of Nicaragua.

Smaragdia ISSEL, 1869

Smaragdia viridis viridemar MAUREY, 1917. Range: southeast Florida, Bermuda, Veracruz to Yucatan, Mexico, and the Caribbean. P, t. Common.

LITTORINIDAE

LITTORINA FÉRUSAC, 1822

Littorina ziczac (Gmelin, 1791). Range: southern Florida to Texas, Bermuda and the Caribbean, the Pacific side of Panama near the canal and South America to Uruguay. P, r, 1, 2. Abundant in splash zone.

Littorina lineolata ORBIGNY, 1842. Range: southern Florida to Texas and the Caribbean. P, r, 1, 2. ABBOTT, 1964, has pointed out the close resemblance between this species and *L. ziczac*. *Littorina lineolata* was usually found in wetter areas; it is smaller and of a deeper color. Abundant in intertidal zone.

Littorina nebulosa (LAMARCK, 1822). Range: the Gulf of Mexico and the Caribbean. P, r, 1. Found on rocks, trees, and debris. Common.

Nodilittorina VON MARTENS, 1897

Nodilittorina tuberculata (MENKE, 1828). Range: southern Florida, Bermuda and the Caribbean. P, r, 1. Common in holes and pitted surfaces on rocks.

Tectarius VALENCIENNES, 1833

Tectarius muricatus (LINNAEUS, 1758). Range: lower

Florida Keys, Bermuda and the Caribbean. P, r, 1. Common on rocks and vegetation.

TRUNCATELLIDAE

Truncatella RISSO, 1826

Truncatella pulchella bilabiata PFEIFFER, 1839. Range: southeast U.S. and the Caribbean. P, r, 1. Common in rotting vegetation under rocks and debris.

RISSOIDAE

Rissoina ORBIGNY, 1840

Rissoina chesneli (MICHAUD, 1830). Range: southeast U.S. and the West Indies. P, beach drift. Common.

Rissoina decussata (MONTAGU, 1803). Range: North Carolina to the Lesser Antilles and Central America. P, beach drift. Uncommon.

Rissoina aberrans (C. B. ADAMS, 1850). Range: Gulf of Mexico and the Caribbean. P, beach drift. Uncommon.

Rissoina toroensis (OLSSON & MCGINTY, 1958). Range: Central America. P, beach drift. Uncommon.

Rissoina cancellata PHILIPPI, 1847. Range: southeast Florida and the West Indies. P, beach drift. Uncommon.

Rissoina sp. P, beach drift. Common.

Rissoina sp. P, beach drift. Common.

Zebina H. & A. ADAMS, 1855

Zebina browniana (ORBIGNY, 1842). Range: Carolinas to the West Indies. P, t. Under stones and debris in *Thalassia* beds; beach drift. Abundant.

Alvania RISSO, 1826

Alvania auberiana (ORBIGNY, 1842). Range: West Indies. P, beach drift. Uncommon.

Alvania chiriquiensis OLSSON & MCGINTY, 1958. Range: Central America. P, beach drift. Rare.

VITRINELLIDAE

Vitrinella C. B. ADAMS, 1852

Vitrinella elegans OLSSON & MCGINTY, 1958. Range: Central America. P, beach drift. Rare.

Vitrinella heliocoidea C. B. ADAMS, 1850. Range: southeast U.S., the West Indies, and the east coast of Central America. P, beach drift. Uncommon.

Cyclostremiscus PILSBRY & MCGINTY, 1945

Cyclostremiscus jeannae PILSBRY & MCGINTY, 1945. Range: Central America. P, beach drift. Uncommon.

Cyclostremiscus schrammii (FISCHER, 1857). Range:

Guadeloupe and Central America. P, beach drift. Uncommon.

Cyclostremiscus ornatus OLSSON & MCGINTY, 1958.

Range: Florida and the Caribbean. P, beach drift. Uncommon.

Teinostoma H. & A. ADAMS, 1854

Teinostoma megastoma (C. B. ADAMS, 1850). Range: Carolinas to the Caribbean. P, beach drift. Common.

Parviturboides PILSBRY & MCGINTY, 1950

Parviturboides interruptus (C. B. ADAMS, 1858). Range: South Carolina to Gulf of Mexico and the Caribbean. P, beach drift. Common.

Solariorbis CONRAD, 1865

Solariorbis blakei REHDER, 1944. (?) Range: South Carolina to the Gulf of Mexico and the Caribbean. P, beach drift. Rare.

Solariorbis infracarinata GABB, 1881. Range: North Carolina to the Gulf of Mexico and the Caribbean. P, beach drift. Uncommon.

Solariorbis sp. P, beach drift. Rare.

Vitrinorbis PILSBRY & OLSSON, 1952

Vitrinorbis elegans OLSSON & MCGINTY, 1958. Range: Central America. P, beach drift. Rare.

Circulus JEFFREYS, 1865

Circulus semisculptus (OLSSON & MCGINTY, 1958).

Range: southern Florida and Central America. P, beach drift. Uncommon.

Macromphalina COSSMANN, 1888

Macromphalina sp. P, beach drift. Rare.

ARCHITECTONICIDAE

Heliculus ORBIGNY, 1842

Heliculus bisulcatus ORBIGNY, 1845. Range: southeast U. S. and the Caribbean. P, beach drift. Uncommon.

Heliculus infundibuliformis (GMELIN, 1791). (?) Range: Caribbean. P, beach drift. Rare.

VERMETIDAE

Petalococonchus H. C. LEA, 1843

Petalococonchus irregularis (ORBIGNY, 1842). Range: southern Florida and the Caribbean. P, r, 2. Cemented on rocks. Common.

Stephopoma MÖRCH, 1860

Stephopoma myrakeenae OLSSON & MCGINTY, 1958.

Range: Central America. P, beach drift. Uncommon.

CAECIDAE

Caecum FLEMING, 1813

Caecum pulchellum STIMPSON, 1851. Range: eastern U. S. and the Caribbean. P, beach drift. Common.

Caecum jucundum FOLIN, 1867. Range: Caribbean. P, beach drift. Abundant.

Caecum ryssotitum FOLIN, 1867. Range: Florida and the Caribbean to Brazil. P, beach drift. Abundant.

Caecum clava FOLIN, 1867. Range: Caribbean. P, beach drift. Rare.

Caecum cycloferum FOLIN, 1867. Range: Central America. P, beach drift. Rare.

Caecum sp. P, beach drift. Rare.

PLANAXIDAE

Planaxis LAMARCK, 1822

Planaxis lineatus (DA COSTA, 1778). Range: lower Florida Keys and the Caribbean. P, r, 2. Abundant beneath rocks.

Planaxis nucleus (BRUGUIÈRE, 1789). Range: southeast Florida and the Caribbean. P, r, 2. Abundant on rocks.

MODULIDAE

Modulus GRAY, 1842

Modulus modulus (LINNAEUS, 1758). Range: Florida to Texas, Bermuda, and the Caribbean to Brazil. P, t. Screened in *Thalassia* beds. Uncommon.

Modulus carchedonius (LAMARCK, 1822). (?) Range: Greater Antilles to the north coast of South America and Central America. P, beach drift. Rare.

CERITHIIDAE

Cerithium BRUGUIÈRE, 1789

Cerithium variabile C. B. ADAMS, 1845. Range: southern Florida to Texas and the Caribbean. P, t, r, 2. Abundant in July; uncommon in March.

Cerithium eburneum BRUGUIÈRE, 1792. Range: southeast Florida, the Bahamas and the Greater Antilles, to Central America. P, r, 5; t. Abundant on rocks; uncommon in *Thalassia* area.

Cerithium auricoma SCHWENGEL, 1940. Range: Florida and the Caribbean. P, beach. Uncommon.

Bittium GRAY, 1847

Bittium varium (PFEIFFER, 1840). Range: Maryland to Florida, Texas, Mexico and the Caribbean. P, t. Under

rocks and debris in *Thalassia* beds. Uncommon; common in beach drift.

Alaba H. & A. ADAMS, 1853

Alaba incerta (ORBIGNY, 1842). Range: Bermuda, Bahamas, southeast Florida and the Caribbean. P, t. Screened in deeper portions of *Thalassia* beds. Also found in beach drift. Uncommon.

Cerithiopsis FORBES & HANLEY, 1851

Cerithiopsis greeni (C. B. ADAMS, 1839). Range: Cape Cod to Florida and the Caribbean. P, t. Common alive under stones in *Thalassia* beds. Abundant in beach drift.

Cerithiopsis regulosum (C. B. ADAMS, 1850). Range: Caribbean. P, beach drift. Uncommon.

Cerithiopsis latum (C. B. ADAMS, 1850). Range: Greater Antilles and Central America. P, beach drift. Uncommon.

Cerithiopsis pupa DALL & STIMPSON, 1901. Range: Greater Antilles and Central America. P, beach drift. Rare.

Cerithiopsis emersoni (C. B. ADAMS, 1838). Range: Massachusetts to the Caribbean. P, r, 5. Rare.

Cerithiopsis bicolor (C. B. ADAMS, 1845). P, r, 5. Screened in green algae on rocks. Rare.

Seila A. ADAMS, 1861

Seila adamsi (H. C. LEA, 1845). Range: Massachusetts to Florida, Texas and the Caribbean. P, t. Common under stones and also in beach drift.

TRIPHORIDAE

Triphora BLAINVILLE, 1828

Triphora turritiformae HOLTEN, 1802. Range: Caribbean. P, t. Also in beach drift. Uncommon.

Triphora nigrocineta (C. B. ADAMS, 1839). Range: Massachusetts to Florida, Texas and the Caribbean. P, t. Uncommon.

Triphora ornata DESHAYES, 1832. Range: Florida and the Caribbean. P, beach drift. Rare.

Triphora pulchellum C. B. ADAMS, 1850. Range: Caribbean. P, beach drift. Uncommon.

Triphora sp. P, beach drift. Uncommon.

EPITONIIDAE

Epitonium RÖDING, 1798

Epitonium krebsi (MÖRCH, 1874). Range: southern Florida to Lesser Antilles and Central America. P, beach drift. Uncommon.

Epitonium albidum (ORBIGNY, 1842). Range: south Florida to Argentina. P, t. Rare.

Epitonium lamellosum (LAMARCK, 1822). Range: southern Florida and the Caribbean. Also Europe. P, beach drift. Uncommon.

Epitonium candeanum (ORBIGNY, 1842). Range: southern Florida to the Barbados and Central America. P, uncommon in beach drift.

EULIMIDAE

Balcis LEACH, 1847

Balcis intermedia (CANTRAINE, 1835). Range: New Jersey to the Caribbean. Also Europe. P, t. Uncommon.

Balcis conoidea KURTZ & STIMPSON, 1851. Range: Florida, the Gulf of Mexico and the Caribbean. P, uncommon in beach drift.

Balcis sp. P, beach drift. Uncommon.

Balcis sp. P, beach drift. Uncommon.

Eulima RISSO, 1826

Eulima auricincta ABBOTT, 1958. Range: southern U. S. to Greater Antilles and Central America. P, uncommon in beach drift.

STILIFERIDAE

Stilifer BRODERIP, 1832

Stilifer subulatus BRODERIP & SOWERBY, 1832. Range: Caribbean. P, rare in beach drift.

Athleenia BARTSCH, 1946

Athleenia burryi BARTSCH, 1946. Range: southern Florida and eastern Costa Rica. P, rare in beach drift.

HIPPONICIDAE

Cheilea MODEER, 1793

Cheilea equestris (LINNAEUS, 1758). Range: southeast Florida and the Caribbean. P, common in beach drift.

Hipponix DEFRANCE, 1819

Hipponix antiquatus (LINNAEUS, 1767). Range: south-east Florida and the Caribbean. P, common in beach drift.

Hipponix subrufus subrufus (LAMARCK, 1822). (?) Range: southeast Florida and the Caribbean. P, common in beach drift.

FOSSARIDAE

Fossarus PHILIPPI, 1841

Fossarus orbigny FISCHER, 1864. Range: Caribbean. P, common in beach drift.

Fossarus sp. P, beach drift. Uncommon.

STROMBIDAE

Strombus LINNAEUS, 1758

Strombus gigas LINNAEUS, 1758. Range: southeast Florida, Bermuda and the Caribbean. P. Only a few broken pieces of this species were found.

Strombus pugilis LINNAEUS, 1758. Range: southeast Florida through the Caribbean to Brazil. P, m. This species was found in deeper water in the center of the lagoon on a bottom covered with sediment and a fine algal mat. It was abundant in July. The specimens appear to be typical *S. pugilis* and do not have the characteristics of *S. pugilis nicaraguensis* as described by FLUCK in 1905.

Strombus raninus GMELIN, 1791. Range: southeast Florida and the Caribbean. P, t. Uncommon.

ERATOIDAE

Trivia BRODERIP, 1837

Trivia leucosphaera SCHILDER, 1931. Range: southeast U. S. and the Caribbean. P, beach drift. Uncommon.

CYPRAEIDAE

Cypraea LINNAEUS, 1758

Cypraea zebra LINNAEUS, 1758. Range: southeast Florida and the Caribbean. P, r, 2. Found with egg masses in March. Uncommon under large rocks.

Cypraea cinerea GMELIN, 1791. Range: southeast Florida and the Caribbean. P, beach drift. Common.

NATICIDAE

Polinices MONTFORT, 1810

Polinices lacteus (GUILDING, 1834). Range: southeastern U. S. and the Caribbean. P, beach drift. Uncommon. FLUCK (1905) found it abundant in Nicaragua.

CASSIDIDAE

Cypraeacassis STUTCHBURY, 1837

Cypraeacassis testiculus (LINNAEUS, 1758). Range: southeast Florida, Bermuda and from South Mexico and the Caribbean to Brazil. P. Uncommon.

CYMATIDAE

Charonia GISTEL, 1848

Charonia variegata (LAMARCK, 1816). Range: southeast Florida and the West Indies. P, r, 3, 4. Usually covered with thick coralline algal growth. Common.

Cymatium RÖDING, 1798

Cymatium pileare (LINNAEUS, 1758). Range: southeast-

ern U. S. to the Caribbean. P, beach drift. Common.

BURSIDAE

Bursa RÖDING, 1798

Bursa cubaniana (ORBIGNY, 1842). Range: southeast Florida and the Caribbean. P, r, 2. Uncommon under large rocks in March.

TONNIDAE

Tonna BRUNNICH, 1772

Tonna maculosa (DILLWYN, 1817). Range: southeast Florida and the Caribbean to Brazil. P, beach fragments. Uncommon.

MURICIDAE

Drupa RÖDING, 1798

Drupa nodulosa (C. B. ADAMS, 1845). Range: southern Florida and the Caribbean. P, r, 2; t. Common under rocks.

Risomurex OLSSON & MCGINTY,

1958

Risomurex roseus (REEVE, 1856). Range: throughout the Caribbean. P, r, 2. Uncommon under rocks.

Risomurex muricoides (C. B. ADAMS, 1845). Range: Caribbean. P, beach drift. Uncommon.

Purpura BRUGUIÈRE, 1789

Purpura patula (LINNAEUS, 1758). Range: southeast Florida and the Caribbean. P, r, 2. Found in depressions on wave-dashed rocks. LEWIS (1960) stated that this species feeds on *Acanthopleura granulata*, which is abundant in this zone. Common. Larger specimens eroded.

Thais RÖDING, 1798

Thais rustica (LAMARCK, 1822). Range: southeast Florida, Bermuda and the Caribbean. P, r, 2, 3. Common.

Thais deltoidea (LAMARCK, 1822). Range: Florida, Bermuda and the Caribbean. P, r, 2, 3. Found on rocks covered with *Hypnea* and *Acanthophora*. Common.

Aspella MÖRCH, 1877

Aspella paupercula (C. B. ADAMS, 1850). Range: Caribbean. P, t. Uncommon under rocks and dead *Porites* coral.

MAGILIDAE

Coralliophila H. & A. ADAMS, 1853

Coralliophila caribaea ABBOTT, 1958. Range: southeast Florida and the Caribbean. P, t, r, 4. Uncommon.

COLUMBELLIDAE

Columbella LAMARCK, 1799

Columbella mercatoria (LINNAEUS, 1758). Range: southeast Florida and the Caribbean. P, t. Uncommon on *Thalassia* blades.

Anachis H. & A. ADAMS, 1853

Anachis catenata (SOWERBY, 1844). Range: Bermuda and the Caribbean. P, r, 3, 4. Found in colonies under rocks and coral heads. Uncommon.

Anachis obesa (C. B. ADAMS, 1845). Range: Virginia to Florida, the Gulf of Mexico and the Caribbean. P, r, 2, t. Common under stones.

Anachis pulchella (SOWERBY, 1844). Range: Florida Keys and the Caribbean. P, t. Rare.

Anachis sp. P, beach drift. Rare.

Nitidella SWAINSON, 1840

Nitidella ocellata (GMELIN, 1791). Range: lower Florida Keys, Bermuda and the Caribbean. P, beach drift. Uncommon.

Psarostola REHDER, 1943

Psarostola monilifera (SOWERBY, 1894). Range: Florida and the Caribbean. P, uncommon in beach drift.

BUCCINIDAE

Bailya M. SMITH, 1944

Bailya parva (C. B. ADAMS, 1850). Range: Bahamas and the Caribbean. P, t, r, 4. Found under dead *Porites* coral and in company with *Aspella paupercula* under coral heads.

Bailya intricata (DALL, 1883). (?) Range: southern Florida and the Caribbean. P, t. Uncommon under stones and rubble.

Antillophos WOODRING, 1928

Antillophos candei (ORBIGNY, 1853). (?) Range: southeast U. S. and the Caribbean. P, t. Uncommon under dead *Porites* coral.

Engina GRAY, 1839

Engina turbinella (KIENER, 1836). Range: lower Florida Keys and the Caribbean. P, t. Found under stones in sheltered areas. Common.

Engina sp. P, beach drift. Rare.

Colubraria SCHUMACHER, 1817

Colubraria lanceolata MENKE, 1828. Range: southeast U. S. and the Caribbean. P, beach drift. Uncommon.

Pisania BIVONA-BERNARDI, 1832

Pisania pusio (LINNAEUS, 1758). Range: southeast Florida and the Caribbean. P, r, 4. Uncommon.

Cantharus RÖDING, 1798

Cantharus auritulus (LINK, 1807). Range: southeast Florida, south through the Caribbean to Brazil. P, beach specimens. Rare.

NASSARIIDAE

Nassarius DUMÉRIL, 1806

Nassarius vibex (SAY, 1822). Range: Cape Cod to Florida, the Gulf States and the Caribbean. P, t. Found on *Thalassia* in deeper water.

Nassarius albus (SAY, 1826). Range: southeastern U. S. to the Caribbean. P, beach drift. Uncommon.

Nassarius nanus USTICKE, 1959. Range: Caribbean. P, t. Uncommon.

FASCIOLARIIDAE

Leucozonia GRAY, 1847

Leucozonia nassa (GMELIN, 1791). Range: Florida to Texas and the Caribbean. P, r, 2, 3. Common under rocks covered with coralline algae.

Leucozonia ocellata (GMELIN, 1791). Range: Florida and the Caribbean. P, beach specimen.

XANCIDAE

Vasum RÖDING, 1798

Vasum muricatum (BORN, 1778). Range: southern Florida and the Caribbean. P, t, r, 4. Common on rocks and debris.

OLIVIDAE

Oliva BRUGUIÈRE, 1789

Oliva reticularis LAMARCK, 1811. Range: southeast Florida, the Bahamas and the Caribbean. P; B. Beach fragments. Rare.

Agaronia GRAY, 1839

Agaronia testacea (LAMARCK, 1811). Range: Central America and in the Panamic Province from the Gulf of California to Peru. P, t. FLUCK (1905) found this species to be abundant in Nicaragua and observed the living animals. OLSSON (1958) also listed it from Panama. TRYON (1883) found it to be indistinguishable from *A. hiatula* (GMELIN, 1791) from West Africa and added that both species exhibited a wide variation in both color and form. Uncommon, dead.

Olivella SWAINSON, 1831

Olivella minuta LINK, 1897. Range: Caribbean. P, beach drift. Uncommon. This may be the subspecies *O. minuta marmosa* since OLSSON & MCGINTY, 1958, list it as occurring nearby in Panama.

MITRIDAE

Mitra LAMARCK, 1799

Mitra nodulosa (GMELIN, 1791). Range: southeast U. S. and the Caribbean. P, r, 4. Uncommon under coral heads.

Mitra barbadensis (GMELIN, 1791). Range: from southeast Florida to the Caribbean. P, uncommon.

Mitra olsoni MCGINTY, 1955. (?) Range: southeastern Florida and Central America. P, beach drift. Rare.

Pusia SWAINSON, 1840

Pusia gemmata (SOWERBY, 1874). Range: Florida and the Caribbean. P, r, 5. Common under rocks and on algae.

MARGINELLIDAE

Marginella LAMARCK, 1799

Marginella denticulata CONRAD, 1830. Range: southeast U. S. to the Caribbean. P, beach drift. Common.

Bullata JOUSSEAUME, 1875

Bullata ovuliformis (ORBIGNY, 1842). Range: the southeast U. S. and the Caribbean. P, uncommon in beach drift.

Persicula SCHUMACHER, 1817

Persicula adamsiana weberi OLSSON & MCGINTY, 1958. Range: Central American coast. P, rare in beach drift.

Persicula lavalleana (ORBIGNY, 1842). Range: southern Florida and the Caribbean. P, uncommon in beach drift.

Hyalina SCHUMACHER, 1817

Hyalina avena KIENER, 1834. Range: southeast U. S. and the Caribbean. P, uncommon in beach drift.

Hyalina tenuilabra TOMLIN, 1917. Range: Florida to the Caribbean. P, uncommon in beach drift.

CONIDAE

Conus LINNAEUS, 1758

Conus regius GMELIN, 1791. Range: Florida to southern Mexico, the Bahamas and the Caribbean south to Brazil. P, r, 4. No living specimens were taken.

Conus mus HWASS, 1792. Range: southern Florida to the Caribbean. BURCH (1960) records this species as occurring in the eastern Pacific at Panama Bay. P, r, 2, 3.

Common on exposed rocky shelves covered with *Hypnea* and *Acanthophora*.

TURRIDAE

Crassispira SWAINSON, 1840

Crassispira fuscescens (REEVE, 1843). Range: Florida Keys to the Caribbean. P, r, 5. Common in shady, protected areas.

Leptadrillia WOODRING, 1928

Leptadrillia splendida BARTSCH, 1934. Range: Caribbean. P, beach drift. Uncommon.

Mangelia RISSO, 1826

Mangelia fusca (C. B. ADAMS, 1845). Range: Caribbean. P, t. Common under rocks, on *Thalassia* leaves, and in beach drift.

Pyrgocythara WOODRING, 1928

Pyrgocythara coxi FARGO, 1953. (?) Range: Florida, the greater Antilles and Central America. P, beach drift. Uncommon.

ONCHIDIIDAE

Onchidella GRAY, 1850

Onchidella sp. P, r, 1, 2. Abundant on damp rocks.

ACTEONIDAE

Acteon MONTFORT, 1810

Acteon finlayi MCGINTY, 1955. Range: southeast Florida and Cuba to Central America. P, beach drift. Rare.

BULLIDAE

Bulla LINNAEUS, 1758

Bulla striata BRUGUIÈRE, 1792. Range: west coast of Florida to Texas and the Caribbean. P. Common as beach specimens.

ATYIDAE

Atys MONTFORT, 1810

Atys caribaea (ORBIGNY, 1841). (?) Range: from southeast Florida to the Caribbean. P, r, 5. Found on green algae and rocks in shady, protected areas. Common.

RETUSIDAE

Retusa BROWN, 1827

Retusa cande ORBIGNY, 1841. Range: Caribbean. P, uncommon in beach drift.

Retusa oxytatus BORN, 1885. Range: southeast U. S. and the Caribbean. P, uncommon in beach drift.

ACTEOCINIDAE

Acteocina GRAY, 1847

Acteocina inconspicua OLSSON & MCGINTY, 1958.

Range: Central America. P, uncommon in beach drift.

APLYSIIDAE

Aplysia LINNAEUS, 1767

Aplysia brasiliana RANG, 1828. Range: Atlantic Ocean from New Jersey to St. Helena. P, r, 2, 3. Found in intertidal and rock-shelf zones. Common on rocks covered with *Hypnea* and *Acanthophora*.

Aplysia sp. P, t. Animals difficult to detect due to light green color and darker green reticulations. Foot white, lightly mottled with purple. Uncommon.

Aplysia dactylomela RANG (?) 1828. Range: world-wide in warm seas. P, r, 2. Intertidal zone. Common on rocks covered with red algae.

PYRAMIDELLIDAE

Cingulina A. ADAMS, 1860

Cingulina babylonica (C. B. ADAMS, 1845). Range: Bermuda and the Caribbean. P, beach drift. Common.

Miralda A. ADAMS, 1863

Miralda havanensis PILSBRY & AGUAYO, 1933. Range: southern Florida to the Caribbean. P, beach drift. Common.

Miralda abbotti OLSSON & MCGINTY, 1958. Range: Central America. P, beach drift. Uncommon.

Odostomia FLEMING, 1817

Odostomia sp. P, beach drift. Common.

Odostomia sp. P, beach drift. Uncommon.

OXYNOEIDAE

Oxynoe RAFINESQUE, 1819

Oxynoe antillarum MÖRCH, 1863. Range: southeast Florida to the Caribbean. P, t. Animals brilliant green and quite active. Common on *Caulerpa*.

Lobiger KROHN, 1847

Lobiger souwerbii FISCHER, 1856. Range: southeast Florida, the Caribbean to Brazil. P, t. Uncommon on *Caulerpa* with *Oxynoe*.

ELLOBIIDAE

Pedipes MÜHLEFELD, 1818

Pedipes mirabilis MÜHLEFELD, 1818. Range: Florida to

the Caribbean. P, r, 1. Common under damp rocks and rotting vegetation in colonies.

Tralia GRAY, 1840

Tralia ovula (BRUGUIÈRE, 1789). Range: Bermuda, Florida, West Indies and the Caribbean coast of Central America. P, r, 1. Common under damp rocks and rotting seaweed.

Melampus MONTFORT, 1810

Melampus coffeus (LINNAEUS, 1758). Range: Florida to the West Indies and Caribbean coast of Central America. P, r, 1. Abundant under rocks and debris, feeding on rotting vegetation.

PELECYPODA

ARCIDAE

Arca LINNAEUS, 1758

Arca imbricata BRUGUIÈRE, 1789. Range: North Carolina to the Caribbean. P, beach drift. Common.

Barbatia GRAY, 1847

Barbatia dominicensis (LAMARCK, 1819). Range: southeast U. S., the Lesser Antilles and Central America. P, r, 2. Common in large groups under coral and rocks.

Arcopsis VON KOENEN, 1885

Arcopsis adamsi (E. A. SMITH, 1888). Range: North Carolina, the Caribbean to Brazil. P, r, 2, t. Abundant under rocks, in large groups.

Anadara DESHAYES, 1830

Anadara ovalis (BRUGUIÈRE, 1789). Range: Cape Cod to the Gulf States and the Caribbean. P, beach specimens. Uncommon.

ISOGNOMONIDAE

Isoignonon LIGHTFOOT, 1786

Isoignonon alatus (GMELIN, 1791). Range: southern Florida to the Caribbean. P, r, 2. Found in large clusters attached in sheltered crevices on rocks. Common.

Isoignonon radiatus ANTON, 1839. Range: southeast Florida to the Caribbean. P, r, 2. Attached in fissures on rocks and usually closer to shore than *I. alatus*. Common.

PTERIIDAE

Pteria SCOPOLI, 1777

Pteria colymbus RÖDING, 1798. Range: southeast U. S. to

the Caribbean. P, r, 2. Uncommon. Attached to rocks in sheltered areas. Found only in March.

SPONDYLIDAE

Spondylus LINNAEUS, 1758

Spondylus americanus HERMANN, 1781. Range: Florida and the Caribbean. P, beach specimens.

LIMIDAE

Lima BRUGUIÈRE, 1797

Lima scabra (BORN, 1778). Range: southeast Florida and the Caribbean. P, beach specimens.

CRASSATELLIDAE

Crassinella GUPPY, 1874

Crassinella martinicensis (ORBIGNY, 1842). Range: Caribbean. P, beach drift. Common.

Crassinella guadalupensis (ORBIGNY, 1842). Range: Caribbean. P, beach drift. Common.

CONDYLOCARDIIDAE

Condylocardia BERNARD, 1896

Condylocardia bernardi (DALL, 1903). Range: Caribbean. P, beach drift. Common.

DREISSENIDAE

Mytilopsis CONRAD, 1857

Mytilopsis domingensis (RÉCLUZ, 1852). Range: Caribbean. P, m. Found near fresh water creek attached to stones. Common.

DIPLODONTIDAE

Diplodonta BRONN, 1831

Diplodonta notata DALL & SIMPSON, 1901. Range: Florida to the Greater Antilles and Central America. P, beach drift. Uncommon.

LUCINIDAE

Phacoides GRAY, 1847

Phacoides pectinatus (GMELIN, 1791). Range: southeast U. S., Texas and the Caribbean. P, t. Common in sand under *Thalassia*.

Anodontia LINK, 1807

Anodontia alba LINK, 1807. Range: southeast U. S. and the Caribbean. P, t. Uncommon. *Anodontia edentuloides* is the Panamic analogue.

Codakia SCOPOLI, 1777

Codakia orbicularis (LINNAEUS, 1758). Range: Florida

to Texas and the Caribbean. P, t. Common in sand under *Thalassia* beds. *Codakia distinguenda* is a closely related species in the Pacific.

Codakia orbiculata (MONTAGU, 1808). Range: southeast U. S. and the Caribbean. P, t. Uncommon, dead valves.

Codakia costata ORBIGNY, 1842. Range: southeast U. S. and the Caribbean. P, uncommon in beach drift.

CHAMIDAE

Chama LINNAEUS, 1758

Chama macerophylla GMELIN, 1791. Range: southeast U. S. and the Caribbean. P, r, 2, 3. Common attached to rocks in protected places.

Chama congregata CONRAD, 1833. Range: southeast U. S. and the Caribbean. P, t. Common as dead valves in beach drift.

VENERIDAE

Chione MÜHLFELD, 1811

Chione cancellata (LINNAEUS, 1767). Range: southeast U. S. to Texas and the Caribbean. P, t. Only immature specimens taken in sand under *Thalassia*. Rare.

Tivela LINK, 1807

Tivela mactroides (BORN, 1778). Range: Caribbean south to Brazil. P; B. Common as single valves on beaches. The Panamic analogue is *T. byronensis* (GRAY, 1838).

Pitar RÖMER, 1857

Pitar dione (LINNAEUS, 1758). Range: Texas and the Caribbean. B, common as beach specimens. *Pitar lupanaria* (LESSON, 1830) is a closely related species in the Pacific.

TELLINIDAE

Tellina LINNAEUS, 1758

Tellina alternata SAY, 1822. Range: southeast U. S., the Gulf of Mexico and the Caribbean. B, on the beach with soft parts. Shell completely pink. Uncommon.

Tellina lineata TURTON, 1819. (?) Range: Florida and the Caribbean. P, t. Uncommon.

Tellina sp. P, beach drift.

Arcopagia BROWN, 1827

Arcopagia fausta (PULTENEY, 1799). Range: southeast U. S. and the Caribbean. P, t.

Strigilla TURTON, 1822

Strigilla carnaria (LINNAEUS, 1758). Range: southeast U. S. and the Caribbean. B, beach specimens. Abundant.

SEMELIDAE

Semele SCHUMACHER, 1817

Semele purpurascens (Gmelin, 1791). Range: southeast U.S. and the Caribbean. P, beach specimens. Uncommon.

Semele nuculoides (Conrad, 1841). Range: southeast U.S. and the Caribbean. P, beach specimens. Uncommon.

DONACIDAE

Donax LINNAEUS, 1758

Donax denticulatus Linnaeus, 1758. Range: Caribbean. B. Some specimens unusually large. Common, burrowing at the edge of the surf.

Iphigenia SCHUMACHER, 1817

Iphigenia brasiliensis (Lamarck, 1818). Range: southern Florida and the Caribbean. P, beach specimens. Uncommon. Fluck (1905) found it plentiful in Nicaragua. The Panamic analogue is *I. altior* (Sowerby, 1833).

MACTRIDAE

Mactra LINNAEUS, 1767

Mactra alata Spengler, 1802. Range: Caribbean to Brazil. Also occurs in the Pacific. P; B, beach specimens. Abundant. This species is eaten by the natives.

Mulinia GRAY, 1837

Mulinia cleyana Orbigny, 1846. Range: Caribbean to Brazil. B, beach specimens. Common.

CORBULIDAE

Corbula BRUGUIÈRE, 1792

Corbula sp. P, beach drift. Uncommon.

PHOLIDIDAE

Martesia BLAINVILLE, 1824

Martesia striata (Linnaeus, 1767). Range: west Florida to Texas and the Caribbean. Also occurs in the Pacific. P, in driftwood.

Pholas LINNAEUS, 1758

Pholas campechiensis Gmelin, 1791. Range: North Carolina to Brazil, Caribbean, Senegal to Liberia. B, beach specimens. Common. This species is the analogue of *P. chilensis* Molina, 1782 of the Pacific.

PERIPLOMATIDAE

Periploma SCHUMACHER, 1817

Periploma inaequalis Schumacher, 1817. Range: Caribbean. B, beach specimens. Uncommon.

AMPHINEURA

CRYPTOPLACIDAE

Acanthochitona GRAY, 1821

Acanthochitona rhodeus Pilsbry, 1893. Range: Caribbean. P, r, 2. Uncommon under rocks and in dark places.

Acanthochitona sp. P, r, 2. Rare under rocks.

ISCHNOCHITONIDAE

Ischnochiton GRAY, 1847

Ischnochiton pectinatus (Sowerby, 1849). Range: Caribbean. P, r, 2. Common under rocks and in dark places.

Ischnochiton sp. P, r, 2. Rare under rocks.

Callistochiton DALL, 1882.

Callistochiton sp. P, r, 2. Rare under rocks.

CHITONIDAE

Chiton LINNAEUS, 1758

Chiton tuberculatus Linnaeus, 1758. Range: Caribbean. P, r, 2. Common in groups under wet rocks. Glides quickly away from light when disturbed.

Chiton marmoratus Gmelin, 1791. Range: Caribbean. P, r, 2. Uncommon. This species is quite active and shows a negative phototropic reaction.

Acanthopleura GÜLDING, 1829

Acanthopleura granulata (Gmelin, 1791). Range: southern Florida and the Caribbean. P, r, 1, 2. The most abundant chiton and seen everywhere in groups.

SCAPHOPODA

SIPHONODONTALIDAE

Cadulus PHILIPPI, 1844

Cadulus sp. P, beach drift.

DENTALIIDAE

Dentalium LINNAEUS, 1758

Dentalium sp. P, beach drift.

Dentalium sp. P, beach drift.

CEPHALOPODA

SPIRULIDAE

Spirula LAMARCK, 1799

Spirula spirula (Linnaeus, 1758). Range: worldwide. B, beach specimens.

OCTOPODIDAE

Octopus LAMARCK, 1798

Octopus vulgaris LAMARCK, 1798. Range: Connecticut to Florida, the Caribbean and Europe. P, t, r, 2, 3, 4. Common.

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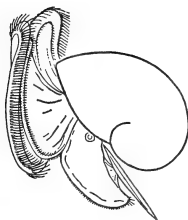
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"*Ptychodon*" *misoolensis* ADAM & VAN BENTHEM JUTTING, 1939
 a New Guinea Strobilopsid Land Snail
 and Review of the Genus *Enteroplax*

BY

ALAN SOLEM

Field Museum of Natural History, Chicago, Illinois

(1 Text figure; 1 Map)

SINCE PUBLISHING A REVIEW of Pacific Island land snail distributions (SOLEM, 1959 a), I have written several papers (SOLEM, 1959 b, 1964 a, 1964 b) concerning the family position of puzzling genera whose accepted family assignment produced geographically discordant data. During preparation of major monographic reviews on the Pacific Island, Australian, Melanesian and New Zealand endodontid land snails, many additional changes in family position have been discovered. The reclassification of *Ptychodon misoolensis* ADAM & VAN BENTHEM JUTTING, 1939, as *Enteroplax misoolensis* is presented separately because of the great zoogeographic interest inherent in this change.

Basic data on the Strobilopsidae have been summarized by PILSBRY (1927 - 1931, pp. 1 - 63 and 1948, pp. 848 to 868). Subsequent descriptions by HO & LEONARD (1961) of fossil *Strobilops* from the Great Plains and of the Bermuda *S. (Disco)strobilops* *pilsbryi* and the West Mexican *S. (D.) sinaloa* by MORRISON (1953) do not alter the basic patterns.

The family is common in the Eocene to Pliocene fossil beds of Western Europe, but is absent from the European Pleistocene and Recent faunas. Several species live in the United States and Canada south of about 52° N Latitude and generally east of the 100°W meridian. Mid-Pliocene fossils are known from the High Plains regions of Kansas and Oklahoma (TAYLOR, 1960). Records are sparse for Northern Mexico. *Strobilops aenea mexicana* PILSBRY (1927, pp. 32 - 33) is known from near Monterrey, Nuevo Leon and Necaxa, Puebla (also see PILSBRY, 1953, p. 165); *S. sinaloa* MORRISON, 1953, probably from Sinaloa; *S. hubbardi* (A. D. BROWN, 1861) from San Luis Potosi, Mexico (PILSBRY, 1927, p. 49); *S. strebeli* (PFEIFFER, 1862) and *S. veracruzensis* PILS-

BRY, 1927 (pp. 33 - 37) from Vera Cruz; and *S. hannai* PILSBRY, 1931, from Socorro Island, West Mexico. *Strobilops strebeli guatemalensis* HINKLEY, 1927 and *S. salvini* (TRISTAN, 1863) are known from Guatemala. There are three peripheral South American records - *S. helleri* (DALL, 1900) from the Galapagos; *S. brasiliana* FRED BAKER, 1913 from Pará, Brazil; and *S. morsei* (DALL, 1885) from Puerto Cabello, Venezuela. *Strobilops piratica* PILSBRY, 1930, from Old Providence Island, *S. wenziana* PILSBRY, 1930, from Grand Cayman and forms of *S. hubbardi* (A. D. BROWN) from Bermuda, Cuba and Jamaica comprise the West Indian records. Data on the above are summarized by PILSBRY (1927 to 1931).

Two Asian groups complete the known taxa. The section *Eostrobilops* PILSBRY, 1927, consists of 4 species - *Strobilops nipponica* PILSBRY, 1927 from Yonezawa, Uzen, Japan; *S. hirasei* PILSBRY, 1927 from Cheju, Quelpart Island, Korea; *S. coreana* PILSBRY, 1927, from Pyong-Yang, North Korea; and *S. diodontina* HEUDE, 1885 from Tchen-k'ou, China (probably is Ch'eng-k'ou, northeast Szechuan Province = Szechwan, at about 108° 47' long., 31° 56' lat.).

Enteroplax GÜDE, 1899, previously was thought confined to the Philippine Islands. There are 5 named taxa representing 4 species, with available data on the previously included species summarized by PILSBRY (1927 to 1931, pp. 50 - 56). *Strobilops quadrasi* (MOELLENDOFF, 1893) from Northern Luzon and *S. polyptychia* (MOELLENDOFF, 1887) from Cebu Island are easily recognizable as distinct species. *Strobilops trochospira* (MOELLENDOFF, 1887) from Mt. Licos, Cebu Island is quite similar to *E. misoolensis*. FAUSTINO (1930, p. 116) listed these as "*Plectroplis*" in the "Helicidae" together

with the endodontid *Stenopylis coarctata* (MOELLEN-DORFF, 1894). GUDE (1899, p. 149) separated *Enteroplax* as a section, but indicated it probably was of generic level separation. A review of this taxon is presented below.

Enteroplax GUDE, 1899

Low conic to discoidal shells with prominent radial ribs above threaded periphery and in umbilicus, sculpture absent on body whorl below periphery. Edge of parietal callus strongly elevated, upper parietal lamella fusing with it anteriorly. Parietal lamellae 2, extending posteriorly about $\frac{1}{2}$ whorl, upper high and blade-like, smooth or serrate on expanded upper edge, 2nd much lower and usually slightly recessed, rarely with a short and deeply recessed interparietal lamella, sometimes a callus connecting the inner ends of the parietals. No columellar lamella. Palatal wall with 3 to 10 short to long lamellae recessed about $\frac{1}{4}$ to $\frac{1}{2}$ whorl behind aperture, connected posteriorly by a transverse callus. Anatomy unknown.

Type Species: *Plectopylis quadrasi* MOELLEN-DORFF, 1893, by OD.

Originally considered as related to the corillid genus *Plectopylis*, their strobilopisid nature was recognized by PILSBRY, 1908. References to the early literature are contained in PILSBRY (1927-1931, pp. 50-56). They are not repeated here in the list of references, although included in the synonymies. While PILSBRY (1948, pp. 848-868) continued to treat the family Strobilopisidae as monotypic on the generic level, ZILCH (1959, p. 178) raised *Enteroplax* to generic level. I concur with this decision, since there is a greater morphologic gap between the shell of *Enteroplax* and those classified as subgenera or sections of *Strobilops*, than between any of the latter. The elevation of the parietal callus and development of a threaded edge to the periphery are not extraordinary changes, but their presence in *Enteroplax* and absence from all other groups of *Strobilops*, s.l. is sufficient for generic recognition.

The 3 Philippine Island species were previously reported from Luzon, Siquijor, Bohol and Cebu Islands. A new record from Mindanao is added below. The Misool Island *Ptychodon misoolensis* ADAM & VAN BENTHEM JUTTING, 1939, proved to be a fourth species. Specimens of *Enteroplax quadrasi* and *E. polyptychia* were available at Field Museum of Natural History (hereafter FMNH). Through the kindness of Dr. Adolf Zilch, Natur Museum Senckenberg, Frankfurt am Main (hereafter SMF), it was possible to examine specimens of *E. trochospira*. Study of the Misool species was possible through the cooperation of Mrs. W. S. van Benthem

Jutting (Zoologisch Museum, Amsterdam, ZMA) and Dr. W. Adam (Institut Royal des Sciences Naturelles de Belgique, IRB). This work was supported by National Science Foundation grants G-16419, GB-3384 and GB-6779. For preparation of the illustrations I am indebted to Miss Margaret Moran. Mrs. Sandra Rendleman, Mrs. Lynda Hanke and Mrs. Rita Mecko assisted in various aspects of this study.

Measurements of the specimens are summarized in Table 1 and enable separation of the entities. All measurements were made with an ocular micrometer to the nearest 0.035 mm. It soon became obvious that the characters used to separate species — number of palatal lamellae, presence or absence of an interparietal lamella, presence or absence of a transverse parietal callus, and degree of serration on the parietals — were highly variable and, in certain cases, that species definitions were based on aberrant conditions. Only 26 adult examples were available. A few statements concerning similarities of populations are possible, but considerably more material will be required before the exact relationships of *Enteroplax quadrasi*, *E. trochospira* and *E. misoolensis* are clarified. The latter species apparently lacks serrations on the parietal lamellae, but the two former have the same apertural dentition and are separable only on size and overlapping shape differences that may be bridged when more populations are sampled.

Outline figures of the Philippine Island taxa, drawn with the aid of a camera lucida on a Wild M-5 microscope, are presented in Figure 1 to indicate the rather subtle shape differences separating *Enteroplax quadrasi* and *E. trochospira*. All indications of radial sculpture have been omitted from the drawings, since there is no interspecific variation in sculptural characters and addition of this feature would have been very time-consuming.

Enteroplax quadrasi (MOELLEN-DORFF, 1893)

(Figures 1 b, 1 c)

Plectopylis quadrasi MOELLEN-DORFF, 1893, Nachr. deut. Malak. Gesell. 25 (11-12): 172-173 — Siamiam, northern Luzon, Philippine Islds.; GUDE, 1897, Science Gossip 4 (39): 71; figs. 54a-54e; MOELLEN-DORFF, 1898, Abhdl. naturf. Ges. Görlitz 22: 122; FAUSTINO, 1930, Philippine Journ. Sci. 42 (1): 116

Plectopylis quadrasi subsp. *boholensis* MOELLEN-DORFF, 1898, Abhdl. naturf. Ges. Görlitz 22: 123 — Bohol, Philippine Islands (nude name)

Helix (*Plectopylis*) *quadrasi* (MOELLEN-DORFF), HIDALGO, 1891, Mem. Real. Acad. Cienc. Madrid 14: 167 — Buguey, Sitio Siam-Siam en Claveria Sitio Dimacapag y Cabayo en Palanen, Camino de Ambubuc, Prov. Cagayan, Luzon (not the cited figs. on pl. 156, figs. 9, 10)

Table 1
Local Variation in *Enteroplax*

	Number of Specimens	Ribs	Height	Diameter	H/D Ratio	Whorls	D/U Ratio
<i>Enteroplax</i> <i>quadrasi</i>							
Luzon							
FMNH 48337-8	4	87.3±4.19 (82-97)	2.13±0.036 (2.04-2.20)	3.58±0.068 (3.42-3.75)	0.596±0.0038 (0.588-0.606)	5½ - (5½-6)	3.66±0.085 (3.45-3.86)
Bohol							
FMNH 48341-2	3	88.5±2.04 (86-91)	2.16±0.044 (2.07-2.20)	3.66±0.058 (3.55-3.75)	0.590±0.0062 (0.583-0.598)	6½ - (5½-6½)	3.35±0.097 (3.17-3.50)
Mindanao							
FMNH 54943	1	107	2.40	3.68	0.652	6½	4.31
<i>trochospira</i>							
Cebu							
SMF 9287/6	8	96.8±1.57 (90-101)	2.32±0.030 (2.20-2.43)	4.14±0.026 (4.05-4.24)	0.561±0.0070 (0.535-0.597)	5½ + (5½-5½)	3.63±0.050 (3.41-3.88)
SMF 118092/2							
<i>misoolensis</i>							
Misool							
ZMA, IRB	6	79.8±8.29 (67-104)	2.63±0.055 (2.43-2.80)	4.18±0.066 (3.88-4.34)	0.629±0.0144 (0.573-0.664)	6½ (5½-6½)	4.22±0.068 (4.00-4.45)
<i>polyptychia</i>							
Cebu							
FMNH 48339-40	4	115	1.48±0.036 (1.38-1.55)	4.03±0.028 (3.98-4.08)	0.368±0.0109 (0.339-0.388)	5½ + (5½-5½)	2.83±0.031 (2.75-2.88)

Plectopylis trochospira var. *boholensis* GUDE, 1898, Science Gossip 4 (46): 285, fig. 74 - Bohol, Philippine Islds.
Strobilops (*Enteroplax*) *quadrasi* (MOELLENDORFF), WENZ, 1916, Nachr. deutsch. Malak. Gesell. 48 (4): 189; PILSBRY, 1931, Man. Conch. (2) 28: 55-56; pl. 11, figs. 11-14
Strobilops (*Enteroplax*) *quadrasi* var. *brunneicincta* "MOELLENDORFF," WENZ, 1916, Nachr. deutsch. Malak. Gesell. 48 (4): 189 - nude name
Strobilops (*Enteroplax*) *boholensis* (GUDE), PILSBRY, 1931, Man. Conch. (2) 28: 54-55; pl. 11, figs. 1-4, 7-10

Range: Luzon, Bohol and Mindanao, Philippine Islands.

Material: LUZON - Tayabas (1 specimen, FMNH 48388); Palanan (3 specimens, FMNH 48337). BOHOL - Batuan (1 specimen, FMNH 48341); Vilar (2 specimens, FMNH 48342). MINDANAO - east slope of Mt. McKinley, Davao at 7000 feet elevation (1 specimen, FMNH 54943).

Remarks: Separation into two species seems to have resulted from chance inspection of aberrant specimens. The Luzon Island *Enteroplax quadrasi* was reported by MOELLENDORFF as having only 3 palatals, but 3 of the 4 specimens seen by me had 4 palatals and only one had 3 palatals. Similarly, the form described as *boholensis* was

recorded to have an interparietal lamella and 5 palatals, but all material that I saw lacked the interparietal and had only 4 palatals. The size and shape of the Luzon and Bohol specimens are identical except in whorl count and a statistically insignificant difference in D/U ratio (Table 1). Without more differences than revealed by study of these specimens, separation of these populations cannot be maintained. Reported differences in parietal serration are a factor of wear after death and correlate with worn versus unworn external sculpture.

A single shell collected on Mindanao (Figure 1c) has been referred here provisionally. Although identical in size to the other *Enteroplax quadrasi* samples, the shell is obviously higher and with a narrower umbilicus. It has typical parietals and 4 palatals. Whether this is another atypical specimen, or is representative of populations that are consistently higher and with narrower umbilici cannot be known without further collections. In the latter case, subspecific separation may be justifiable.

Enteroplax quadrasi differs from both *E. trochospira* and *E. misoolensis* in size. Other differences are bridged by variation between populations and probably have no great significance.

Enteroplax trochospira (MOELLENDOFF, 1887)

(Figure 1a)

Plectopylis trochospira MOELLENDOFF, 1887, Jahrb. deutsch. Malak. Gesell. 14 (3): 273-274; pl. 8, figs. 9a-9c - Mt. Licos, Cebu, Philippine Islds.; MOELLENDOFF, 1890, Ber. Senckenb. naturf. Gesell. 1890: 221; MOELLENDOFF, 1897, Abhdl. naturf. Ges. Götting 22: 123; GUDE, 1898, Science Gossip 4 (46): 285; figs. 73a-73e; FAUSTINO, 1930, Philippine Journ. Sci. 42 (1): 116

Helix (Plectopylis) trochospira (MOELLENDOFF), HIDALGO, 1890, Mem. Real. Acad. Cienc. Madrid 14: 118, 167 (1891) - Sitio Cambague en Vilar y Sierra Bullones, Bohol, Philippine Islds. (not cited figs. on pl. 156)

Strobilops (Enteroplax) trochospira (MOELLENDOFF), WENZ, 1916, Nachr. deutsch. Malak. Gesell. 48 (4): 189; PILSBRY, 1931, Man. Conch. (2) 28: 52-53; pl. 11, figs. 5a-5c, 6a-6c

Range: Cebu, Philippine Islands.

Material: CEBU - Mt. Licos (8 specimens, SMF 9287/6 paratypes, SMF 118092/2).

Remarks: Differences in spire shape and elevation (see Figures 1a to 1c) between *Enteroplax quadrasi* and *E. trochospira* are subtle. Extremes of both species show a slight overlap. There is a distinct size difference (Table 1) with the height and diameter not overlapping, although the whorl counts are nearly identical. Examined specimens of *E. trochospira* showed 4 (5 specimens) or 5 (1 specimen) palatals that were connected posteriorly by a transverse callus and showed no structural differences from the lamellae seen in *E. quadrasi*. With some hesitation I am accepting them as distinct species.

In size, *Enteroplax trochospira* and *E. misoolensis* are identical, but the latter is distinctly more elevated, has a narrower umbilicus, the parietal lamellae are not serrated above, and averages $\frac{1}{2}$ whorl more.

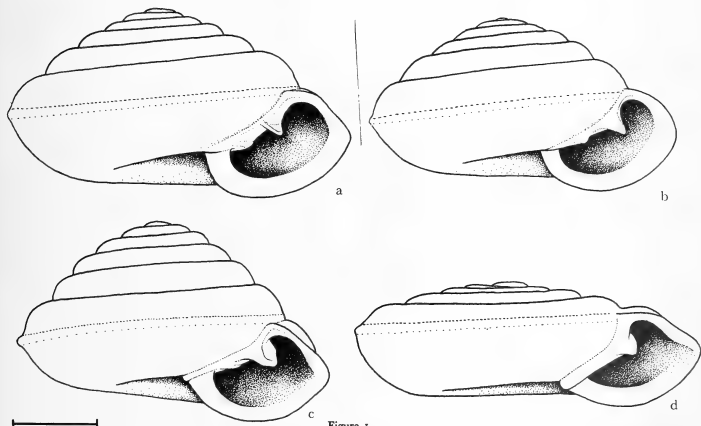


Figure 1

Shells of

a: *Enteroplax trochospira* (MOELLENDOFF), Mt. Licos, Cebu, Philippine Islands; SMF 9287/6; Paratype. b, c: *Enteroplax quadrasi* (MOELLENDOFF), b: Palanan, Luzon, Philippine Islands. FMNH 48337; c: Mt. McKinley, Davao, Mindanao, Philippine Islands; FMNH 54943; d: *Enteroplax polytychia* (MOELLENDOFF), Mt. Licos, Cebu, Philippine Islands; FMNH 48339. Probable paratype. Scale line equals 1 mm

Enteroplax polyptychia (MOELLENDORFF, 1887)

(Figure 1d)

Plectoplys polyptychia MOELLENDORFF, 1887, Jahrb. deut. Malak. Gesell. 14 (3): 272-273; pl. 8, figs. 8a-8c — Mt. Licos, Cebu, Philippine Islds.; MOELLENDORFF, 1890, Ber. Senckenb. naturf. Gesell. 1890: 221; MOELLENDORFF, 1897, Abhdl. Naturf. Ges. Götting 22: 122 — Siquijor, Philippine Islds.; GUDE, 1898, Science Gossip 4 (40): 102; figs. 55a-d; FAUSTINO, 1930, Philippine Journ. Sci. 42 (1): 116

Helix (Plectoplys) polyptychia (MOELLENDORFF), HIDALGO, 1890, Mem. Real. Acad. Cienc. Madrid 14: 118, 167 (1891) — not the cited figures on pl. 156

Strobilops (Enteroplax) polyptychia (MOELLENDORFF), WENZ, 1916, Nachr. deut. Malak. Gesell. 48 (4): 188 to 189; PILSBRY, 1931, Man. Conch. (2) 28: 52; pl. 12, figs. 14-16

Range: Cebu and Siquijor, Philippine Islands.

Material: CEBU — Mt. Licos (3 specimens, FMNH 48339, probable paratypes); Barili (1 specimen, FMNH 48340).

Remarks: No Siquijor material was seen, but I have no reason to question MOELLENDORFF's identification. In its greatly depressed shape and wider umbilicus, *Enteroplax polyptychia* is immediately separable from the other species. Although described as having about 9-10 minute palatal lamellae, 2 of the 3 examples checked had the typical 3 or 4 palatals found in other *Enteroplax*. Although obviously distinctive, the depressed spire and wider umbilicus are linked characters caused by the change in coiling pattern. Since the tooth pattern as originally described is known to be aberrant, this species is now shown to differ only in the single linked pair of changes.

Enteroplax misoolensis (ADAM & VAN BENTHEM JUTTING, 1939)

Pytychodon (Nesophila) misoolensis ADAM & VAN BENTHEM JUTTING, 1939, Bull. Mus. Roy. Hist. Nat. Belg. 15 (17): 1-3; fig. 1 — forest 10 km north of Lilita, Misool Is., in *Asplenium*; ADAM & LELOUP, 1939, Mem. Mus. Roy. Hist. Nat. Belg. (hors ser.) 2 (20): 16; pl. 2, fig. 9

Pytychodon misoolensis ADAM & VAN BENTHEM JUTTING, 1958, Nova Guinea 9 (2): 327

Nesophila misoolensis (ADAM & VAN BENTHEM JUTTING), VAN BENTHEM JUTTING, 1964, Nova Guinea 26: 11

Diagnosis: Shell large, diameter 3.89-4.35 mm (mean 4.18 mm) with 5½-6½ tightly coiled whorls. Apex and spire strongly elevated, slightly rounded above, H/D ratio 0.573-0.664 (mean 0.629). Umbilicus broadly "U"-shaped, barely decoiling, contained 4.00-4.45 times (mean 4.22) in the diameter, with somewhat shouldered

margins. Upper surface of shell with irregularly protractive radial ribs, 67-104 (mean 79.8) on the last whorl, whose interstices are less than twice their width. Major ribs absent from below periphery of body whorl but reappearing within umbilicus. Periphery of body whorl protruding and narrowly keeled. Aperture ovate, inclined about 25° from the shell axis. Parietal lamellae 2, extending well beyond line of vision: upper high, blade-like, attaining its greatest height at anterior end, becoming bifurcated and forming raised edge to parietal callus; lower less than ½ the height of the upper, stopping short of parietal callus edge. Palatal wall with 4-5 short lamellae recessed ⅓ to ¼ whorl within aperture.

The smooth parietal lamellae, moderately narrower umbilicus, slightly more elevated spire and higher whorl count separate *Enteroplax misoolensis* from the Philippine *E. trochospira*. *Enteroplax quadrasi* is perhaps most similar in shape, but differs in its smaller size and serrated parietal lamellae.

Description: Shell large, with 6½ tightly coiled whorls. Apex and spire strongly and almost evenly elevated, slightly rounded above, H/D ratio 0.621. Apical whorls 1½, sculpture of vaguely radially oriented granulosities. Remaining whorls with prominent, irregularly shaped, protractive radial ribs, about 67 on the body whorl, which are much less prominent near the suture and absent from the body whorl below the narrow periphery, but reappear within the umbilicus. Microsculpture of vaguely reticulated radial and spiral riblets, often obscured by changes in the major growth wrinkles. Umbilicus broadly "U"-shaped, regularly decoiling, contained 4.26 times in the diameter. Sutures relatively shallow, whorls moderately rounded above, somewhat flattened laterally below periphery. Aperture ovate, lip strongly thickened and reflected, inclined about 25° from shell axis. Parietal wall with heavy callus and 2 lamellae extending posteriorly beyond line of vision: upper parietal high, blade-like, sharply descending near anterior margin, then bifurcating to form a raised edge to parietal callus; lower parietal much reduced in height, ridgelike, extending not quite to edge of parietal callus. Columellar wall without lamellae. Palatal wall with 4 lamellae visible from aperture, a 5th seen through the shell, recessed ⅓ to ¼ whorl within aperture. Uppermost tooth thin, low, very short; 2nd much higher, slightly expanded above and longer; 3rd even more prominent; 4th slightly reduced in height and length; 5th trace apparently even shorter. Height of holotype 2.70 mm, diameter 4.35 mm.

Holotype: New Guinea: Misool Island. Collected February 26, 1929 in forest 10 km north of Lilita, on *Asplenium*. Musée Royal d'Histoire Naturelle de Belgique no. 9223.

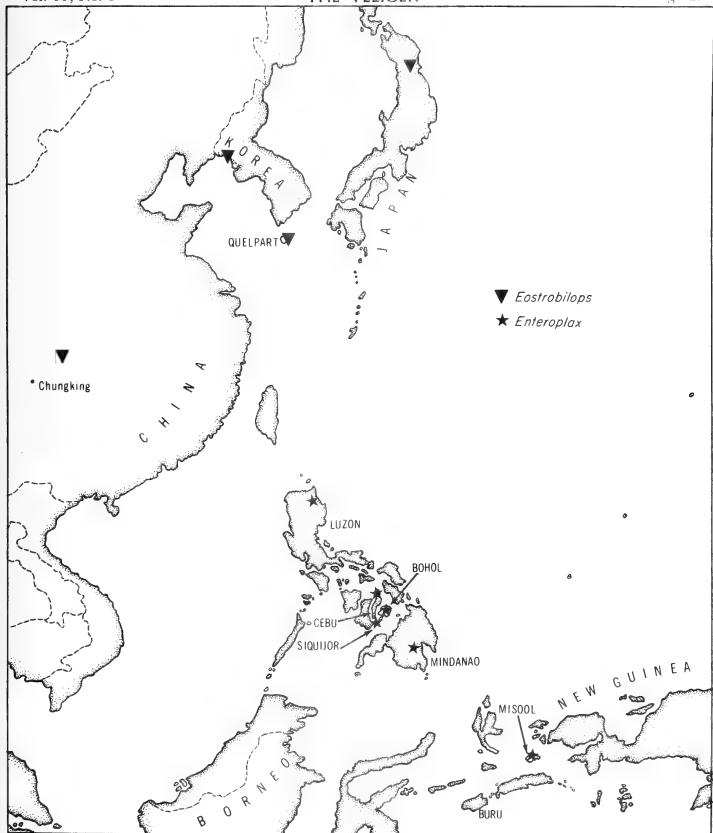


Figure 2

Distribution of *Enteroplax* (★) and *Strobilops* (*Eostrobilops*) (▼)

Paratypes: ZMA and IRB.

Range: Misool Island. Known from near Lilinta, Waima and Fakal.

Material: MISOOL — 10 km north of Lilinta (4 specimens, ZMA, IRB); Waima (3 specimens, ZMA); Fakal (1 specimen, ZMA).

Remarks: Although identical to *Enteroplax trochospira* in size, the absence of any serrations on the upper parietal, distinctly narrower umbilicus, proportionately higher spire, and presence of a half whorl more at the same diameters separate *E. misoolensis*. Only 4 examples had the aperture clear enough or the body whorl sufficiently transparent to enable counting the palatal lamellae — one had 5 palatals and 3 had 4 palatals.

ZOOGEOGRAPHY

Prior to the discovery that *Enteroplax* was present on Misool Island, the distribution of Asian Strobilopsidae appeared anomalous. Species of the section *Eostrobilops* were known from China, Korea and Japan (see Map) with the Philippine Islands containing an endemic subgenus, *Enteroplax*. Viewed from a North Pole perspective, as in PILSBRY (1927 - 1931, p. 15, fig. 2), a derivation of the Philippine *Enteroplax* from the north, using the *deus ex machina* of accidental transport on the feathers of birds would seem logical and reasonable. Extension of the known distribution to Misool Island is highly significant in that it brings the probable derivation of *Enteroplax* into the typical pattern of 1) movement from southeast Asia into Indonesia; 2) reaching the Philippines and Misool; and 3) followed by replacement in the Indonesian area leaving the isolated populations in Misool and the Philippines. Almost certainly populations will be found in New Guinea.

Specimens of *Eostrobilops* lack the raised parietal callosus and the peripheral thread, plus having the parietal lamellae with superior serrated nodes (see PILSBRY, 1927 - 1931, pl. 10, fig. 14). *Enteroplax* and *Eostrobilops* are not closely related to each other and their geographic juxtaposition has no systematic significance.

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Observations on Aquarium Specimens of *Oliva sayana* RAVENEL

BY

AXEL A. OLSSON

1906 Ferdinand Street, Coral Gables, Florida 33134

AND

Mrs. L. E. CROVO

2915 S W 102nd Avenue, Miami, Florida 33165

(Plate 2)

INTRODUCTION

Oliva sayana IS THE COMMON, large *Oliva* in Florida occurring along both coasts, and in some localities quite plentifully although like *Olivella nivea* GMELIN, 1791, fast disappearing in others. It is an excellent aquarium snail with interesting habits and will thrive for many years with minimum attention. Essential is a fairly large or spacious tank of sea water, provided with a deep sand layer, the water kept fresh and well aerated and on occasions changed when cleaning is required. Normally, the snail lies buried in the sand out of sight, the siphonal tube generally protruding above, straight as a stick, or swinging back and forth as if to keep track of what may be taking place above. At meal time, the snails will emerge obediently and accept a great variety of animal food, such as pieces of fish, shrimp, steak, and best of all, other live mollusks such as *Nassarius*, *Donax* and *Laevicardium*. Olives have long been known to be both scavengers as well as active predators on other mollusks but the actual manner of food capture remained imperfectly known. The following notes record some of our observations along this line made over a period of several years.

SNAIL WATCHING

In July 1967, our pastime of *Snail Watching* became even more exciting when several of our aquarium inmates began to produce egg capsules in a seemingly endless procession, a performance repeated at intervals for about three months. Although the egg capsules of *Olivella* and its veligers have been described in detail by MARCUS in Brazil, those of *Oliva* itself remained unre-

corded as far as we have been able to learn. We are offering a few illustrations based on photographs; those of the veligers are experimental and were taken under rather high power. Since a live veliger is a very active little creature, passing in and out of the limited field of view and at different levels, instantaneous exposures were taken and only partial focus secured.

FOOD HABITS

Several years ago the senior author observed *Agaronia* preying on *Olivella* on a beach near Manta, Ecuador. After capture of an *Olivella*, the body of the *Agaronia* would swell up into a rounded ball suggesting that the smaller animal had been directly swallowed. Gently squeezing the body of the *Agaronia*, the *Olivella* would pop out, and placed in a dish of sea water, would quickly recover. As these observations were made in the field, incidental to more pressing duties, it is possible that a mistaken interpretation had been made as suggested by MARCUS (1959). That small mollusks, such as *Ervilia*, *Semelina*, *Caecum*, as well as ostracods and foraminifera, are habitually swallowed by several species of *Olivella* (*O. nivea* (GMELIN, 1791), *O. gracilis* (BRODERIP & SOWERBY, 1829), etc.) is proved, since their shells are commonly found intact and empty in the digestive tract on dissection. Logically, *Oliva* should be able to do the same with even larger forms; but additional observations on this subject are required. Even if the food pieces are large, the following procedure is normal. If pieces of fish, shrimp, or steak be placed in the tank, the Olives soon become aware of them and will begin to emerge and start on a round of investigation. When the food morsel is discovered, it is quickly seized and pushed

back under the foot and infolded in its hinder section as if tucked away in a pocket, which swells up into a rounded ball, the food item hidden away so completely that no part of it is visible externally. The Olive then retreats below sand level, going down head-first. The same procedure is used with live mollusks, such as *Donax* and *Laevicardium*, to which latter *Oliva sayana* is especially partial. A *L. vitellinum* (REEVE, 1844), if placed in the tank, seems to become aware of a lurking danger and will flip about energetically, especially if pursued by an Olive. Large *Laevicardium*, nearly the size of the Olive, may be taken, infolded in the foot, and carried underground. Clams with a rough surface, such as *Chione cancellata* (LINNAEUS, 1767), are consistently rejected.

EGG CAPSULES AND VELIGERS

On July 13, 1967, the junior author noticed that one large *Oliva* had emerged and seemed to be acting rather peculiarly, the lobes of its mantle loose and flabby. At the same time, the surface of the sand appeared as if covered with small, crystal-clear balls, which like miniature balloons swayed and shifted about with the least agitation of the tank water. These balls proved to be transparent egg capsules containing minute white eggs, the capsules varying in shape from nearly spherical to oblong and about 1.7 mm in greatest length and about 1.5 mm in diameter. Each capsule held from 20 to 50 eggs, the eggs at first quite clear, darkening to nearly black as incubation set in. The skin of the capsule is quite tough, flexible when touched with a sharp needle. A group of capsules set apart in a dish of sea water incubated in from 3 to 5 days, the hatched embryos developing rapidly into nearly full-sized veligers which could be seen spinning around within the crowded space of the capsule for a day or more. In about the seventh day, the capsule would puncture at one end, the exit generally so small that only a single veliger could escape at a time, the others pushing on behind. From one capsule closely watched, the average time for the exit of a veliger was one minute and the entire capsule of 38

embryos to empty required a little over half an hour. In several other capsules, the last few veligers, unable to find the tiny exit, perished within. Once out, the veligers were extremely active for about two days, the cilia on their vela vibrating vigorously in a continuous wave-like pattern, producing the visual impression of rapidly rotating blades. Observed from above, the veligers looked like small helicopters with rapidly spinning rotor blades, or like a man on a bicycle, the shell hanging below. Occasionally the velar lobes would fold inward, and the embryo would sink to the bottom, sometimes to rest, or the embryo would begin to spin around actively as if to test, or to bore into, the substrate, for further metamorphosis, then to rise again for another tour about. At first, the velar flaps were clear but as they grew a little larger 4 brown spots appeared. As noticed by MARCUS (1959) for the veligers of *Olivella verreauxii* (DUCROS, 1857), those of *Oliva sayana* RAVENEL, 1834 subsisted entirely on the yolk sacs within; these at first were dark and became gradually lighter in color. None of our veligers were able to undergo further metamorphosis, the substrate evidently being unfavorable.

SUMMARY

The egg capsules of *Oliva sayana* are free, hence subject to dispersal by currents; they differ from those of *Olivella verreauxii*, which are attached (MARCUS, 1959). Whether this distinction is generic remains for future research to determine.

Our observations show that many details of molluscan life may be obtained by patient snail watching of aquarium specimens. Species of *Oliva* lend themselves admirably for this purpose through their ready adaptability to aquarium life, and they possess many interesting habits.

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Explanation of Plate 2

- Figure 1: *Oliva* scouting and sensing shrimp.
Figure 2: *Oliva* going down with shrimp infolded in the foot.
Figure 3: *Oliva* held in hand showing sole of foot, the propodium down and the food package infolded in the hinder section of the foot.
Figure 4: Egg capsule, punctured and partly emptied. One veliger free outside, another part way out. ca. $\times 35$.
Figures 5, 6: Free veligers. ca. $\times 160$. Note small foot, shell, operculum, etc.



Figure 1



Figure 2



Figure 3



Figure 4

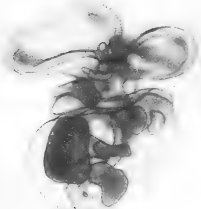


Figure 5

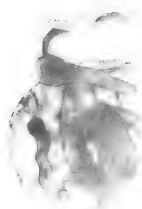


Figure 6



A Record of the Indo-Pacific Cone, *Conus ebraeus*, in Guatemala

BY

WILLIAM K. EMERSON

Department of Living Invertebrates
American Museum of Natural History

Seventy-ninth Street and Central Park West, New York, New York 10024

Conus ebraeus LINNAEUS, 1758, A WIDE-RANGING, shallow water, Indo-Pacific species, was first known to occur in the eastern Pacific at Clipperton Island and in the Galapagos Islands (HERTLEIN, 1937). In 1953, the late Ted Dranga found this species living on the mainland of the west coast of Central America. He reported (*in litt.*) taking a living specimen . . . "in a crevice on an extensive area of hard rock wave bench covered with short sea weed . . ." on the Pacific coast of Guanacaste Province, Costa Rica (HERTLEIN & EMERSON, 1953, p. 351). This record was subsequently cited by KEEN, 1958, p. 480; HANNA, 1963, p. 61; and EMERSON, 1967, p. 89 (recorded erroneously as "*Conus chaldeus* RÖDING"). HOUBRICK (1968) reported collecting two additional living specimens in the intertidal zone near Playas del Coco, Guanacaste Province, Costa Rica, in 1965. According to Dr. Kenneth J. Boss (*in litt.*), one of these specimens, cat. no. 256447, is deposited in the Museum of Comparative Zoology, Harvard University and it is a typical specimen of *Conus ebraeus*.

The American Museum of Natural History recently received from Mrs. Jane Zager of West Orange, New Jersey, a specimen of *Conus ebraeus* that was stated to have been collected by G. Farris on flats exposed by a minus tide at San José, Escauintla Department, Guatemala, in 1947. This specimen, cat. no. 114575, which measures 24.5 mm in length, is nearly identical with one figured by HERTLEIN (1937, plt. 1, fig. 2) from Clipperton Island.

These records indicate that this species may be expected to occur in suitable habitats along the coast of the West Americas within the Panamic faunal province. Collectors should make a special effort to look for this

species and other Indo-Pacific faunal elements when collecting in the coastal waters of this region. At the present time most of the Indo-Pacific species occurring in the tropical eastern Pacific are known only from the oceanic islands, Clipperton, Revillagigedo, Cocos, and the Galapagos, off the west American coast (EMERSON, 1967).

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A Cowrie Mutant from the Gulf of Thailand

BY

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

(1 Text figure)

MUTANTS ARE HEREDITARY VARIANTS which differ from typical specimens by one or a few striking characters; there are no, or only rare, intermediates. The mutants live among the not-varied individuals of the same species and do not show any environmental specialization. They show a distinct center of frequency and become gradually scarcer in populations living around this locality. True mutants differ from morphes (SCHILDER, 1966, p. 185) by their area of distribution being still very restricted, if compared with that of the typical species.

In cowries such local mutants evidently are very rare, as only three variants can be classified in this way: *Ovatipsa chinensis tortirostris* (SOWERBY, 1906) from South Africa (see SCHILDER, 1966, p. 186); *Lyncina carneola titan* SCHILDER & SCHILDER, 1962 from southern Kenya (established as a distinct species), and *Eironca erronea azurea* SCHILDER, 1968, from Broome.

Recently a fourth case has been disclosed by several series of cowries presented to me chiefly by Mr. J. Orr and Mr. Franz B. Steiner: *Mauritia arabica* LINNAEUS, 1758, which formerly was thought to be represented by a single race in the Gulf of Thailand (SCHILDER, 1965, p. 26), has proved to consist of two well separable variants along the east coast of the interior part of this Gulf.

The primary *Mauritia arabica* is mostly small, oblong to ovate, and rather depressed; in shells from the northern Gulf of Thailand the length usually (i. e. in 67% of shells approaching the mean) varies from 43 to 55 mm, the usual breadth from 60 to 62% of length, and the usual height from 48 to 51% of length.

These shells belong to the subspecies *Mauritia arabica asiatica* SCHILDER & SCHILDER, 1939 (ranging from Japan to the Gulf of Thailand) if this "race" really can be separated from the Malayan typical *M. a. arabica* by its lips being more acuminate chiefly at the rear.

The mutant is larger and broader, as its usual length varies from 53 to 66 mm and its breadth from 64 to 69% so that the means differ in a significant way; besides, the outline of the base is rather deltoid (instead of elliptical) and the dorsum is humped, viz. relatively higher (usually 52 to 55% of length, the mean being 54 instead of 50%) and its top is displaced to the rear of the shell so that the shells recall *Trona stercoraria* (LINNAEUS, 1758) in shape (Figure 1). The brown dorsal longitudinal striae are evidently far less interrupted by pale lacunae than it is in the other races of *Mauritia arabica*.

This mutant should be called *Mauritia arabica gibba* COEN, 1949 (see SCHILDER, 1964, p. 104) in spite of the inaccurate type locality "China Sea": for this region also includes the Gulf of Thailand, and COEN's indications of habitat were mostly uncertain or even false.

The extremely broad and callous *Mauritia arabica dilatata* COEN, 1949 (see loc. cit.) becomes a synonym of *M. a. gibba* as it applies to an individual variant of which several specimens have been collected in the populations of the more frequent and less extreme *M. a. gibba*.

The center of distribution of *Mauritia arabica gibba* evidently lies in the islands of the Ko Sichang group (about 70 km SE of Bangkok), especially in Ko Taitamun (see map in Figure 1); here and in the Ko Khrok group (opposite of Pattaya) only has *M. a. gibba* been collected as yet, but no *M. a. arabica*. On the beaches of the mainland, however, from Pattaya to east of Rayong both *M. a. arabica* and *M. a. gibba* have been collected, e. g. in Ban Pe (Bang Pae) and in Ban Klaeng Lang, where the specimens of the species *M. arabica* include 75% and 68% respectively *M. a. gibba*. Farther east, i. e. at Laem Sing and in the Ko Chang group no *M. a. gibba* have been collected at all, as it is, according to Mr. J. Orr, the case also in the whole west coast of the Gulf of Thailand (Hua Hin, Chumporn, Songkla).

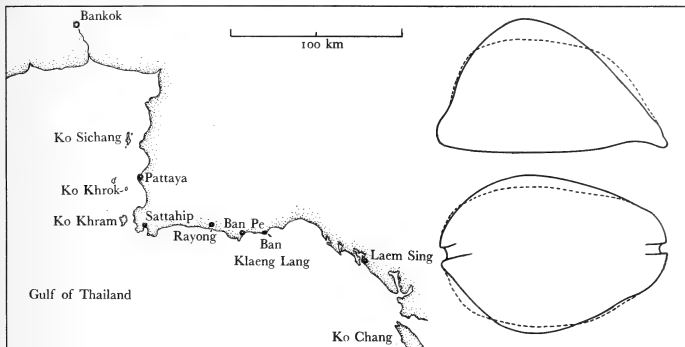


Figure 1

Map of the northeastern Gulf of Thailand. — Right: Profile and basal view of *Mauritia arabica* (dotted line) and of its mutant *gibba* (solid line).

The largest shells of *Mauritia arabica gibba*, varying from 67 to 79 mm, have been collected in a Japanese wreck sunk in the Ko Sichang group during World War II: the dorsum of all specimens is rich chestnut showing the usual dark brown striae; this discoloration varying in intensity shell by shell evidently has been caused by the rusty water in which these animals lived; the base, however, is rather pale as usual.

Therefore *Mauritia arabica gibba* is restricted to the east coast of the northernmost part of the Gulf of Thailand from the Ko Sichang group to Ban Klaeng Lang. The center of the morphologically well separable mutant is in the Ko Sichang group in the innermost part of the Gulf of Thailand, from where it spread about 100 km to the southeast.

Note — The subspecific name *gibba* of COEN, 1949 is not preoccupied by *Cypraea gibba* Gmelin, 1791, because COEN established the name for a members of the genus *Mauritia*. Lumpers, using the single generic name *Cypraea* for all cowries, will be obliged to establish a new name for the secondary homonym: for the only synonym of *gibba*, called *Mauritia (Arabica) arabica dilatata* by COEN, 1949 (see above)

would become also a secondary homonym preoccupied by *Cypraea spurca* var. *dilatata* MONTEROSATO, 1897.

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The Rediscovery of *Voluta (Lyria) grangeri* SOWERBY 3RD, 1900

BY

CLIFTON STOKES WEAVER

Hawaiian Malacological Society, 2777 Kalakaua Avenue, Honolulu, Hawaii 96815

AND

JOHN ELEUTHÈRE DUPONT

Delaware Museum of Natural History, Greenville, Delaware 19807

(Plate 3; 1 Map)

IN JULY OF 1967 we received from Mr. and Mrs. C. N. Cate of Los Angeles an unidentified shell that appeared to be a new volutid species in the genus *Lyria* GRAY, 1847. It had been trawled by pearling luggers during August, 1949 in 5 fathoms of water a few miles north-northwest of Port Hedland, central Western Australia. The arrival of a second specimen from the Cates in October of the same year from the same locality seemed to confirm our opinion. However, further research showed that in 1900 SOWERBY 3RD described and figured *Voluta (Lyria) grangeri*, in the Annals and Magazine of Natural History, ser. 7, vol. 5, p. 440, plt. 11, fig. 2, but he gave no locality data. His figure and description closely resembled the shells in question.

When photographs of the holotype of *Voluta (Lyria) grangeri* arrived from the British Museum (Natural History) in London and we compared them with the Cates' specimens, there remained little doubt that all 3 shells were conspecific.

Since 1900 *Lyria grangeri* seems to have been missing from molluscan literature. We therefore take pleasure in reestablishing *grangeri* as a valid species in the genus *Lyria* and in designating a type locality for it.

Lyrinae PILSBRY & OLSSON, 1954

1954. Lyrinae PILSBRY & OLSSON, Bull. American Paleont. 35 (152): 285, 286

Type Genus: *Lyria* GRAY, 1847.*Lyria* GRAY, 18471847. *Lyria* GRAY, Proc. Zool. Soc. London 15: 141Type Species: *Voluta nucleus* LAMARCK, 1811; Recent, Australia, by OD.(*Lyria*) s. s.*Lyria (Lyria) grangeri* (SOWERBY 3RD, 1900)

(Plate 3, Figures 1 to 6)

1900. *Voluta (Lyria) grangeri* SOWERBY 3RD, Ann. Mag. Nat. Hist. (7) 5: 440, plt. 11, fig. 2 (no locality given).

Type: Holotype, British Museum (Natural History), London, No. 1900.5.22.83.

Type Locality: Here designated a few miles north-northwest of Port Hedland, central Western Australia (see Map).

Explanation of Plate 3

Ventral and Dorsal Aspects of *Lyria (Lyria) grangeri* (SOWERBY 3RD, 1900)

Figures 1, 2: Holotype, ex British Museum (Natural History), No. 1900.5.22.83; no locality data on original label; photographs courtesy BM (NH).

Figures 3, 4: Homeotype No. 1, ex C. N. Cate Coll.; trawled by a pearling lugger several miles NNW of Port Hedland, central

Western Australia in 5 fathoms; photographs by Clifton S. Weaver.

Figures 5, 6: Homeotype No. 2, ex C. N. Cate Coll.; same locality data as for the preceding specimen; photographs by Clifton S. Weaver.

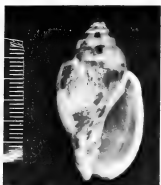


Figure 1

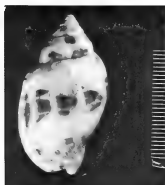


Figure 2

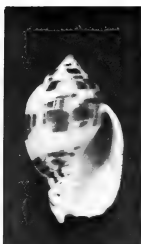


Figure 3



Figure 4

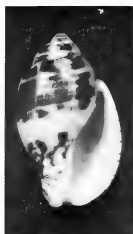


Figure 5



Figure 6

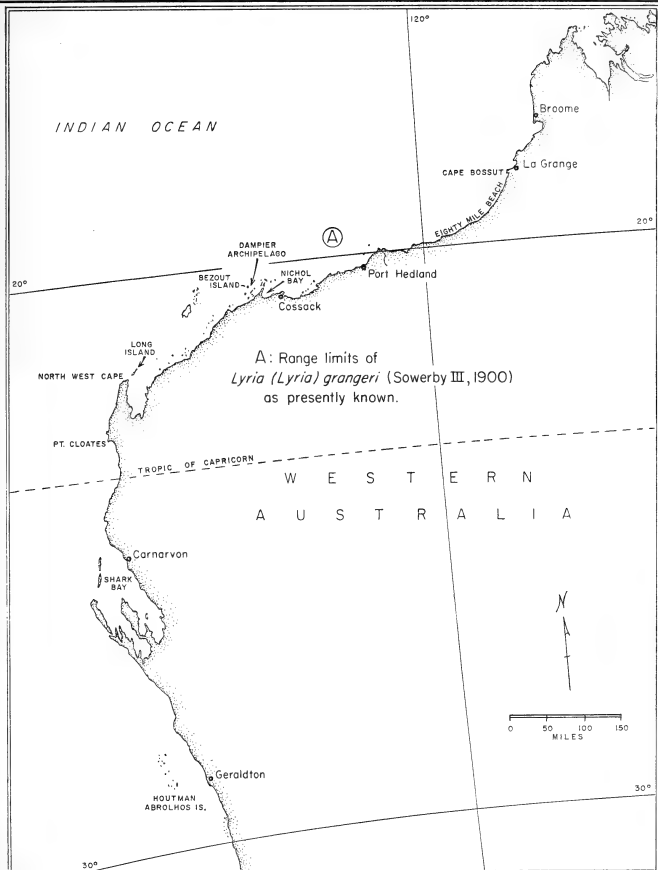


Table 1

Measurements (in millimeters) and Collecting Data for *Lyria (Lyria) grangeri* (SOWERBY 3rd, 1900)

Specimen	Height	Maximum Diameter	Aperture Length	Locality	Collecting Depth in Fathoms	Collection	Growth Stage
Holotype	40.0	21.0	26.5	Unknown	Unknown	BM (NH) No. 1900.5.22.83	Adult
Homeotype No. 1	41.3	24.0	27.2	A few miles NNW of Port Hedland, central Western Australia	5	C. N. Cate	Adult
Homeotype No. 2	42.8	24.6	30.0	A few miles NNW of Port Hedland, central Western Australia	5	C. N. Cate	Adult

BM (NH) = British Museum (Natural History)

Range: Known only from type locality.**Habitat:** In 5 fathoms. Substrate unknown.**Dimensions:** See Table 1.

Shell Description: Shell of medium size for genus, subglobose, light in weight. Spire low, convex; apex blunt. Protoconch small, turbinate, of 2 smooth whorls. Teloconch of 5 swollen whorls indented at sutures. Sculpture consists of low narrow axial ribs extending from suture to suture, these ribs becoming broader and finally obsolete on adult body whorl, about 19 or 20 such ribs on penultimate whorl of shell measuring 42.8 mm in length. Aperture wide, expanding anteriorly; interior a yellowish-cream color. Columella curved inward, with 3 anterior plaits, followed by numerous fine lirae which disappear about midpoint on columella. A small tooth-like projection appears at posterior end of columella below junction of outer lip and body whorl. Outer lip thickened externally to form a parallel raised ridge about 7 mm wide. Siphonal notch wide, shallow; fasciole well defined. Base color creamy-white overlaid with chestnut-brown blotches forming 2 broad bands on body whorl, 1 at periphery and 1 above anterior tip. Fine brown lines, about 2 mm apart, encircle body whorl and intrude just inside outer lip.

Animal and Radula: Unknown.

Remarks: We have removed *Lyria grangeri* from *Voluta* and placed it in the genus *Lyria* for obvious reasons. The species has much in common with *Lyria (Lyria) deliciosa* (MONTROUZIER, 1859) including the small, smooth, turbinate protoconch, axially ribbed early whorls, and the arrangement of columellar plaits and lirae. The single tooth-like projection on the posterior end of the columella also resembles that found in *L. (L.) mitraeformis* (LAMARCK, 1811) and on several other species of *Lyria s. s.*

Although the distribution of *Lyria (Lyria) mitraeformis* extends as far west as Albany, south Western

Australia, no other *Lyria*, to our knowledge, inhabits waters off the central or north Western Australian coasts.

We know of the existence of only 3 specimens of *Lyria (Lyria) grangeri*: The holotype is in the British Museum (Natural History), London, and 2 are in the collection of Mr. and Mrs. Crawford N. Cate; the present whereabouts of a possible fourth specimen, mentioned by SOWERBY 3rd in his original description, is unknown.

ACKNOWLEDGMENTS

We wish to thank our friends, Mr. and Mrs. C. N. Cate for allowing us to see the 2 specimens which triggered this investigation. We are also grateful to Dr. Norman Tebble and the photographic staff at the British Museum (Natural History), London, who kindly sent the type photographs which appear in this paper.

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A List of Types of the Family Volutidae Held by the National Museum of Victoria

BY

BRIAN J. SMITH

Curator of Invertebrates
National Museum of Victoria, Australia

BOTH PRIMARY AND SECONDARY TYPES of the family Volutidae held by the National Museum of Victoria are listed under the original name. The present status in each case is included according to the Second Provisional Species List of Living Volutidae, by C. S. WEAVER (1964).

Cymbiola randalli STOKES, 1961.

Holotype.

Reference: STOKES, A. J., 1961. A new species of Volute from Undine Reef, Queensland *Cymbiola randalli* sp. nov. R. Soc. S. Aust. Malac. Sec. Publ. 16: 3, fig.

Type Locality: 3 miles from Undine Reef, North Queensland on sandy bottom. Collected by Mr. A. J. Randall.

Present Status: Synonym of *Cymbiolacca wisemani* (BRAZIER, 1870)

National Museum of Victoria Reg. No. F 22758

Remarks: Shell only.

Livonia mamilla leucostoma MAYBLOM, 1951.

Holotype.

Reference: MAYBLOM, A. 1951. Deep-sea shells from New South Wales. Aust. Zool., 11 (4): 283; pl. 26, fig. 3.

Type Locality: Below 80 fms. around Gabo Island.

Present Status: Synonym of *Livonia mamilla* (SOWERBY, 1844).

National Museum of Victoria Reg. No. F 19280

Remarks: Shell only.

Voluta hamillei CROSSE, 1869.

Holotype.

Reference: CROSSE, H., 1869. Diagnose d'une espèce nouvelle de *Voluta*. Journ. de Conch., Paris. 17: 278.

CROSSE, H., 1870. Description d'espèces nouvelles. Journ. de Conch., Paris. 18: 97 - 99; pl. 1, fig. 5 and pl. 2, fig. 4.

Type Locality: Japan. In the original description (1869) the type locality was quoted as Solomon Islands. This was corrected to Japan in the next year.

Present Status: *Fulgoraria hamillei* (CROSSE, 1869). Valid Species.

National Museum of Victoria Reg. No. F 26773.

Remarks: Shell only. Specimen purchased from Mr. R. Damon in 1875 for 15 pounds.

Voluta roadnightae McCov, 1881.

Holotype.

Reference: McCov, F, 1881. Description of new Volute from South Coast of Australia. Ann. Mag. Nat. Hist. Fifth. Ser. 8: 88 - 89; pl. 7, figs. 1 and 2.

Type Locality: Southern Coast of Victoria. Type specimen found on the beach, Lake's Entrance, Gippsland, Victoria. Collected by Mrs. Roadnight.

Present Status: *Livonia roadnightae* (McCov, 1881). Valid species.

National Museum of Victoria Reg. No. F 662

Remarks: Shell only. The type specimen was first noticed by the eminent botanist, Baron von Mueller when on a visit to the Gippsland Lakes district where it was serving as a prop to keep his bedroom window open at his hotel.

Voluta (Amoria) spenceriana GATLIFF, 1908

Holotype.

Reference: GATLIFF, J. H., 1908. Description of *Voluta (Amoria) spenceriana*, sp. nov. from North Queensland. Victorian Nat. 25 (5), fig.

Type Locality: North Queensland. Collected by J. F. Bailey.

Present Status: *Amoria spenceriana* (GATLIFF, 1908). Valid species.

National Museum of Victoria Reg. No. F 455

Remarks: Shell only.

Voluta thatcheri McCov, 1868.

Holotype.

Reference: McCov, F, 1868. On a new Volute. Ann. Mag. Nat. Hist. Fourth Ser., 1: 54; pl. 2, fig. 1.

Type Locality: From the type description habitat unknown. Dr. Cox (1872) states that the type specimen was purchased by Mr. C. R. Thatcher in a pawnbroker's shop in Collins Street, Melbourne. Specimens have since been taken alive from Bampton Reefs, north of New Caledonia.

Present Status: *Notovoluta thatcheri* (McCoy, 1868).

Valid species.

National Museum of Victoria Reg. No. F 22764

Remarks: Shell only.

Aulica kellneri IREDALE, 1957.

Paratypes

Reference: IREDALE, T., 1957. Another Australian Volute. Journ. Proc. R. Zool. Soc. N. S.W. 1955-1956 [1957]: 91 to 92; pl. 1.

Type Locality: Eastern Arnhem Land, North Australia. Locality on paratypes - Blythe River Gulf, Northern Territory.

Present Status: Synonym of *Aulica flavicans* (Gmelin, 1791).

National Museum of Victoria Reg. No. F 18192

Remarks: 2 shells.

Cymbiolacca cracenta McMICHAEL, 1963.

Paratype

Reference: McMICHAEL, D. F., 1963. Descriptions of two new species of the genus *Cymbiolacca* IREDALE (Gastropoda: Volutidae). Journ. malac. Soc. Austral. 7: 33 - 41

Type Locality: Dredged in 17 - 20 fathoms 15 miles SE of Cape Green (south of Townsville), Queensland. Collector probably T. Nielsen.

Present Status: *Cymbiolacca cracenta* McMICHAEL, 1963. Valid species.

National Museum of Victoria Reg. No. F 23822

Remarks: One shell.

Cymbiolacca complexa nielseni McMICHAEL, 1959.

Paratype

Reference: McMICHAEL, D. F., 1959. Marine Mollusca of Eastern Australia. 1. The genus *Cymbiolacca* IREDALE (Family Volutidae). Aust. Zool. 12 (4): 374 - 383; pl. 44.

Type Locality: 30 miles off Burnett Heads, Hervey Bay, Queensland, 10 fathoms (locality of the N. M. V. paratype given as off Bundaberg, Queensland).

Present Status: *Cymbiolacca complexa nielseni* McMICHAEL, 1959. Valid subspecies.

National Museum of Victoria Reg. No. F 18259

Remarks: Specimen (shell and animal) in spirit; also a radula slide from the same specimen with the same Reg. No. This is the only type radula slide of this subspecies.

Cymbiolacca peristicta McMICHAEL, 1963.

Paratypes

Reference: McMICHAEL, D. F., 1963. Descriptions of two new species of the genus *Cymbiolacca* IREDALE (Gastropoda: Volutidae). Journ. malac. Soc. Aust. 7: 33 - 41; pl. 6.

Type Locality: Big Sandy Cay, Swain Reefs; dredged 2 fathoms. Collector Mr. T. Nielsen.

Present Status: *Cymbiolacca peristicta* McMICHAEL, 1963. Valid species.

National Museum of Victoria Reg. No. F 22757

Remarks: Two shells.

Nannamoria parabola GARRARD, 1960.

Paratype

Reference: GARRARD, T. A., 1960. A new species of *Nannamoria* (Mollusca: Volutidae) from Southern Queensland. Journ. malac. Soc. Aust. 4: 2 - 13; pl. 1.

Type Locality: 125 fathoms off Moreton Island, Queensland.

Present Status: *Nannamoria parabola* GARRARD, 1960.

Valid species.

National Museum of Victoria Reg. No. F 21107

Remarks: One shell.

Pseudocymbiola provocationis McMICHAEL, 1961

Paratype

Reference: McMICHAEL, D. F., 1961. New Species and new records of marine Mollusca from Australia. Journ. malac. Soc. Aust. 5: 51 - 57; pl. 4, figs. 9 - 10.

Type Locality: Off Port Kembla, N. S. W.

Present Status: *Pseudocymbiola provocationis* McMICHAEL, 1961. Valid species.

National Museum of Victoria Reg. No. F 23821

Remarks: Shell only.

Voluta (Amoria) gatliffi SOWERBY, 1910.

Cotypes

Reference: SOWERBY, G. B., 1910. Description of a new Volute. Ann. Mag. Nat. Hist. Ser. 8, 6: 611.

Type Locality: Port Keats, Northern Territory, Australia. **Present Status:** Synonym of *Amoria damoni* (Gray, 1864).

National Museum of Victoria Reg. No. F 620 & F 5066

Remarks: Shells only. - There may possibly be a third cotype, Reg. No. F 626, but this cannot be found.

Voluta macgillivrayi Cox, 1873.

Paratype

Reference: Cox, J. C., 1873. Distribution of Australian Volutes. Second edition.

Type Locality: Woodlark Island. New Guinea.

Present Status: Synonym of *Aulicina norrisii* (GRAY, 1838).

National Museum of Victoria Reg. No. F 5067

Remarks: Shell only.

Voluta mamilla GRAY, 1844

Figured Specimen

Reference: GATLIFF, J. H. & C. J. GABRIEL, 1909. First record of the animal of *Voluta mamilla*, GRAY; with remarks thereon. Victorian Nat. 26 (8): 117 - 118; pls. 2 & 3, figs. 1 - 5.

Type Locality: 15 miles SW of Gabo Island, Victoria, in

30 fathoms.

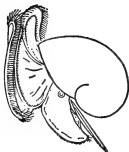
Present Status: *Livonia mamilla* (GRAY, 1844). Valid species.

National Museum of Victoria Reg. No. F 805

Remarks: Radula slide cannot be found. Shell only. Shell and animal of this species all figured.

Also in the collections of the National Museum of Victoria are photographs of a paratype of *Mesericusa stokesi* COTTON, 1961.

Reference: COTTON, B. C., 1961. A new species of Volute, *Mesericusa stokesi* sp. nov. from South Australia. R. Soc. S. Aust. Malac. Sec. Publ. 16: 1; fig.



Mediargo, a New Tertiary Genus in the Family Cymatiidae

BY

JUDITH S. TERRY

Department of Geology, Stanford University, Stanford, California 94306

(Plate 4)

INTRODUCTION

IN THE COURSE OF RESEARCH ON Recent and fossil species of the cymatiid genera *Argobuccinum*, *Fusitriton*, and *Priene*, the writer observed (TERRY, 1968) a number of Pliocene specimens that possess characters of all three genera but could not be assigned to any one. Juveniles resemble Recent species of *Gyrineum* LINK, 1807, and late juveniles are easily confused with those of *Fusitriton oregonensis* (REDFIELD, 1848). Young adults are similar to Recent species of *Argobuccinum* HERRMANNSEN, 1846, while gerontic forms such as the holotype of *Gyrineum lewisii* CARSON, 1926 and the mature specimen figured herein are distinct from all other cymatiids. Specimens of different growth stages have been compared, and 2 species can be recognized: *Mediargo mediocris* (DALL, 1909) of middle or late Miocene to Pliocene age, and *M. mathewsonii* (GABB, 1866), which ranges from the middle Oligocene to middle Miocene. Only the former, the type species, will be considered here.

Mediargo TERRY, gen. nov.

Type Species: *Gyrineum mediocre* DALL, 1909

Specimens referred to *Mediargo* by the writer have

been classified most commonly in *Ranella*, *Bursa* and *Gyrineum*. Although characters, such as lateral varices and anterior pillar folds, are common to all four, the new genus is distinguished by a combination of these and other morphologic features that place it closer to *Argobuccinum* and *Fusitriton*.

Diagnostic generic characters that are seen in all but the largest gerontic specimens include the following: two nearly continuous lateral varices on each volution, high spire, rounded whorls having tabulate shoulders, moderate to long anterior canal, anal notch oriented at an angle to the axis of coiling (as in *Fusitriton*), in contrast to the apically directed notch in *Argobuccinum*), transverse pillar folds over most of the columella, and a denticulate or plicate outer lip. Axial and spiral costae may be marked or obsolete and are commonly present on juvenile whorls but conspicuously lacking in the later stages. *Mediargo* differs from *Argobuccinum* in its tabular whorls and anal notch, from *Fusitriton* in its lateral varices and plicate aperture, and from *Gyrineum* in its outline, tabulate shoulders, ovate aperture, marked anal notch, and large size.

The name *Mediargo* is feminine in gender. It combines the root of *Gyrineum mediocre*, here designated as the type species, and the prefix of *Argobuccinum*, the genus to which it is morphologically most similar.

Explanation of Plate 4

Figure 1: *Mediargo mediocris* (DALL, 1909). Holotype U.S.N. M. No. 153900, Coos Bay, Oregon. Pliocene. Holotype of *Gyrineum mediocre* DALL, 1909. 4.4 cm high.

Figure 2: *Mediargo mediocris* (DALL), LACMIP No. 215596, Palos Verdes Hills, California. "Pleistocene." [reworked Pliocene.] 4.2 cm high.

Figure 3: *Mediargo mediocris* (DALL), Univ. Oregon F 2638, Bandon, Oregon. Mio-Pliocene. 4.2 cm high. Compare variation in sculpture between specimens in Figures 2 and 3.

Figure 4: *Mediargo mediocris* (DALL), CAS No. 11689, from a well in San Diego, California. Pliocene. 4.5 cm high.

Figure 5: *Mediargo mediocris* (DALL), Paratype, USNM No. 645876, Coos Bay, Oregon. Miocene or Pliocene. (Former number was 153900.) 6 cm high.

Figure 6: *Mediargo mediocris* (DALL), LSJU No. 138, Santa Maria District, California. Pliocene. [Paratype of *Gyrineum lewisii* CARSON, 1926.] 6.2 cm high.

Figure 7: *Mediargo mediocris* (DALL), UGMP No. 10105, Coos County, Oregon. Pliocene. Note plicate aperture. 4.6 cm high.

Figures 8, 9: *Mediargo mediocris* (DALL), LSJU No. 31625, Kettleman Hills, Fresno County, California. Pliocene. Mature specimen. 11.3 cm high.

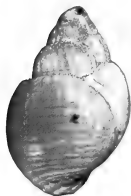


Figure 1



Figure 2



Figure 3



Figure 4

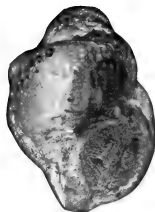


Figure 5



Figure 6

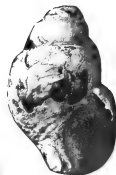


Figure 7



Figure 8



Figure 9

Mediargo mediocris (DALL, 1909)

(Plate 4, Figures 1 to 9)

Gyrineum mediocre DALL, 1909, U. S. Geol. Surv. Prof. Paper 59: 54-55; pl. 7, fig. 6

WEAVER, 1943, Univ. Wash. Publ. Geol. 5 (II): 423-424; (III): pl. 83, fig. 13

Gyrineum lewisii CARSON, 1926, Bull. So. Calif. Acad. Sci. 25: 53-54; pl. 2, figs. 1, 2*Ranella (Priene) mediocris* (DALL): GRANT & GALE, 1931, Mem. San Diego Soc. Nat. Hist. 1: 736*Ranella (Priene) lewisii* (CARSON): GRANT & GALE, 1931, Mem. San Diego Soc. Nat. Hist. 1: 736"Gyrineum" *mediocre lewisii* CARSON: WOODRING & BRAMLETTE, 1950, U. S. Geol. Surv. Prof. Paper 222: 73-74; pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27

Type Information: The holotype, USNM 1539000, and paratype, USNM 645876, were collected by Mr. B. H. Camman from the vicinity of Fossil Point, Coos Bay, Oregon (Lat. 43°23' N, Long. 124°12' W). They are in the type collection of the Division of Invertebrate Paleontology at the Smithsonian Institution, Washington, D. C. Both are worn, incomplete, half grown forms, the holotype measuring 44 mm, the paratype 60 mm in height. DALL (1909) considered them Miocene in age but later workers refer them to the Pliocene. The holotype is certainly Pliocene and the paratype may be either Pliocene or reworked from Miocene beds near Fossil Point.

Descriptive Notes: Mature adult specimens have at least 8 whorls and may be 136 mm or more in height. Two conspicuous, discontinuous lateral varices occur on each whorl, the alignment being more perfect in juvenile forms. Shoulders are tabulate and whorls rounded and inflated. Shells are high spired, a character that is not evident in adults with broken apices. Differences in sculpture are seen in progressive growth stages, which also show considerable intraspecific variability. Numerous axial ribs bearing nodes at the junctions with bifurcated spiral costae are generally present on juvenile whorls but obscure to totally absent in adults. Most Pliocene adult specimens are characterized by sharply incised spiral grooves. If Juveniles pronounced in material from tar seeps in the Santa Maria District, California, incised spirals are not produced by a particular mode of preservation.

The aperture is ovate and modified by a marked anal notch near the posterior parietal callous deposit. The slightly flexed pillar and outer lip bear plications that are present in juveniles and half grown adults, but lacking in large gerontic forms in which the outer lip is flared.

Juveniles of *Mediargo mediocris* have been confused with those of *Fusitriton oregonensis*, although spiral

sculpture differs slightly and *F. oregonensis* lacks pillar furrows and regularly spaced varices. The division between *Mediargo mediocris* (DALL) and *M. mathewsonii* (GABB) is drawn between strongly grooved Pliocene and late Miocene specimens of the former and older, more coarsely sculptured forms of the latter, none of which attains the large size of *M. mediocris* adults.

Distribution in Time and Space: Range: middle (?) or late Miocene to late Pliocene, from the Olympic Peninsula, Washington to San Diego, California.

Stratigraphic units from which the species has been collected include the Quillayute Formation (Pliocene) of Washington, Astoria Formation (Miocene) and Empire Formation (Pliocene) of Oregon, and the Falor, Wildcat, Merced, Etchegoin, Fernando and Niguel Formations (all Pliocene) of California.

ACKNOWLEDGMENTS

Specimens in addition to those in the collections at Stanford University were made available by Drs. Thomas Waller and Druid Wilson of the U. S. National Museum, Dr. Leo G. Hertlein of the California Academy of Sciences, Mr. Joseph Peck of the University of California at Berkeley, Mr. George Kanakoff, Mr. Edward Wilson, and Mr. Louie Marinovich of the Los Angeles County Museum of Natural History, Dr. Warren Addicott and Mr. J. G. Vedder of the U. S. Geological Survey, Menlo Park, and Mrs. Carole Hickman, Department of Geology, University of Oregon. Their kind generosity in providing loans and locality information is gratefully acknowledged. The manuscript was read by Dr. A. Myra Keen, whose suggestions and criticisms are most appreciated.

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TERRY, JUDITH S.

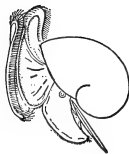
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WOODRING, WENDELL PHILLIPS & MILTON NUNN BRAMLETTE

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The Role of Behavioral Traits in Influencing the Distribution of Two Species of Sea Mussel, *Mytilus edulis* and *Mytilus californianus*

BY

J. R. E. HARGER

Department of Biological Sciences
University of California at Santa Barbara, Santa Barbara, California¹

(3 Text figures)

INTRODUCTION

IN THE COURSE of an investigation into the nature of competitive interactions between two species of sea mussels (*Mytilus edulis* LINNAEUS, 1758 and *M. californianus* CONRAD, 1837) on the coast of Southern California, I discovered that in addition to certain morphological characters which served to differentiate the two species, a difference in behavior was also apparent. Knowledge of this behavior enabled me to account for a difference in the distribution of the two species in large mussel clumps occurring intertidally on pier pilings. The pier concerned (property of Signal Oil & Gas Company) is located at Ellwood, some 14 miles west of the city of Santa Barbara, California, on an open sandy shore. It is constructed from steel girders and is about half a mile long; the pilings support clumps of mussels in the intertidal region, which range in size from a few individuals up to giant masses some 17 feet (5.2 m) in circumference with a vertical extent of around 9 feet (2.7 m).

A. FIELD INVESTIGATION

METHODS

I investigated the distribution of the two species of mussels within the mussel clumps in the following manner. Before removing samples of mussels from the clumps on the pilings, I sprayed the outside animals thoroughly with white enamel paint. This provided an objective

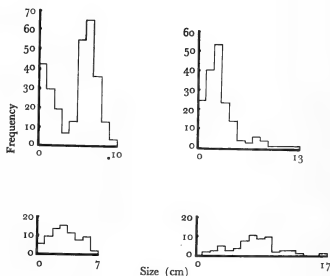


Figure 1

Size distribution of *Mytilus edulis* and *Mytilus californianus* from the inside and outside of a mussel clump at Ellwood Pier. The total sample represents approximately one third (by volume) of a clump measuring 7 feet (2.13 m) in circumference.

Diagram 1: *Mytilus edulis* from outside the clump. Sample size is 262, mean is 4.6 cm

Diagram 2: *Mytilus edulis* from inside the clump. Sample size is 72, mean is 3.5 cm

Diagram 3: *Mytilus californianus* from inside the clump. Sample size is 175, mean is 3.10 cm

Diagram 4: *Mytilus californianus* from outside the clump. Sample size is 53, mean is 7.82 cm

The class interval for each histogram is 1.0 cm.

¹ Present address: Department of Zoology, University of British Columbia, Vancouver, B. C., Canada

Table 1

Numbers of *Mytilus edulis* and *Mytilus californianus* from the inside and outside portions of a sample taken from a mussel clump containing both species. The sample represents approximately one third (by volume) of a clump measuring 7 feet (2.13 m) in circumference.

	Outside		Inside	
	<i>Mytilus californianus</i>	<i>Mytilus edulis</i>	<i>Mytilus californianus</i>	<i>Mytilus edulis</i>
Top	68	117	317	72
Middle	168	555	687	302
Bottom	73	262	343	114

method for determining whether a particular mussel came from inside or outside a cluster. Mussels completely or partly covered with paint were recorded as "outside" mussels and the rest as "inside" mussels (hereafter the term "inside" mussels refers to animals selected in this manner). The mussels were detached by taking a straight hoe and slicing the inside individuals away from a piling face, from the top to the bottom of the aggregation. In this way, a sample of $\frac{1}{4}$ to $\frac{1}{2}$ of the complete clump was removed at one time. I then divided the slab of mussels into 3 equal portions: top, middle, and bottom. Individual mussels of each species then were classified into 6 categories.

e. g.:

Type	<i>Mytilus californianus</i> or <i>Mytilus edulis</i>		
Position	Outside	or	Inside
Depth	Top,	Middle	or Bottom

RESULTS OF FIELD INVESTIGATION

Table 1 records the number and positions of mussels within $\frac{1}{3}$ of a clump measuring 7 feet (2.1 m) in circumference. In mixed aggregations most of the *Mytilus edulis* occur on the outside of the clumps. *Mytilus edulis* juveniles (up to 2.5 cm) tend to be found on the outside of the clumps while *M. californianus* juveniles tend to occur within the body of the clump. Figure 1 illustrates this distribution.

B. LABORATORY INVESTIGATION

METHODS AND RESULTS

For the sake of convenience I will include experiments carried out in the field under the above heading (experiments of this nature were carried out at Ellwood Pier and in the Santa Barbara Harbor).

In the course of studying competition among juvenile mussels (1-2 cm in length), I assembled cages containing *Mytilus edulis* mixed evenly with *M. californianus* (100 individuals of each species). These cages were suspended beneath Ellwood Pier below low water level.

At the first inspection of this experiment (after an immersion interval of 1 month) evidence implying a difference in behavior between the two species was revealed. Most of the *Mytilus edulis* in the cages had moved to the outside of the enclosed clumps, leaving the *M. californianus* in the center. Such a difference in behavior would plainly be of advantage for *M. edulis* in a competitive situation since it would seem reasonable to assume that mussels on the outside of a clump would be the first to capture food particles from the surrounding water and, in addition, would not be pressed upon, and therefore interfered with, by their neighbors. This implied difference in behavior suggested a mechanism which would account for the disparate clump distribution shown by the two mussel species. It seemed reasonable to suppose that any *M. edulis* individuals settling within the matrix of a cluster would move to the outside, attach firmly, and then grow to maturity.

To test the possibility of such a difference in behavior between the two species I took small individuals (1-2 cm) of both species into the laboratory, placed them (separately) about 5 cm below the surface of road gravel (0.5 to 0.75 cm diameter) within perforated plastic containers and immersed these containers in running sea water. Figure 2 records the cumulative numbers of mussels appearing on the surface of the gravel with the passing of time. *Mytilus edulis* obviously crawls out from the gravel at a much higher rate of speed than does *M. californianus*.

When individuals of *Mytilus edulis* were placed 5 cm below the surface of a gravel filled plastic tube (1.5 inches [3.81 cm] in diameter) which was sealed at one end, they always crawled through the gravel, towards and out of the open end of the tube, regardless of whether

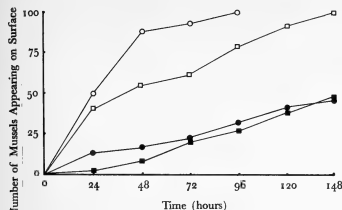


Figure 2

Comparison between the rate of "crawling out" by *Mytilus edulis* and *Mytilus californianus* when both species are initially buried under 5 cm of road gravel.

Two replicate runs for each species are recorded. Solid symbols represent *Mytilus californianus*, open symbols represent *Mytilus edulis*. The total number of animals used for each trial was 100.

the opening faced directly upwards, horizontally or at any intermediary angle.

If small mussels (1-2 cm) are buried in gravel at a depth greater than 13 cm, very few of them are able to crawl to the surface, presumably because the weight of the stones is too great for them to move against. This probably helps to explain why the mussels crawled towards the open end of the tube rather than the closed end.

Initially I had thought that small *Mytilus edulis* might settle within the matrix of the clump of mussels and then crawl to the outside using light as a possible orientation cue. To test this hypothesis I placed 3 cages containing small mussels at a depth of 5 cm below the gravel surface, inside light-tight boxes through which ran sea water. The first cage was illuminated from the top by a directional light beam, the second was illuminated from the side and the third was kept completely dark. All mussels crawled to the top of the cages and no difference in "crawl-out" rate could be detected among the 3 treatments. This indicated that it was not a positive reaction to light which caused *Mytilus edulis* to orient themselves on the outside of the mussel clumps.

This "crawling-out" reaction, then, seems to be evoked in response to some tactile sensation induced by the pressure of objects resting against the mussels. This hypothesis is supported by the fact that when small *Mytilus edulis* are placed separately within the interstices of a cairn of "fist-sized" stones in such a manner that they press neither against themselves nor against the stones, they do not crawl out (except for an occasional individual), but remain fixed in one place.

The only other mussel to occur in large numbers on the coast of Southern California is *Septifer bifurcatus* (CONRAD, 1837), a rather small animal (maximum size 3.5 to 4.5 cm), found only on exposed shores. The crawling behavior of *Septifer* is quite different from that of *Mytilus edulis* or *M. californianus*. When *Septifer* is placed a few centimeters below a gravel surface it does not move from its position. When placed on top of a bed of gravel or on a pitted surface, *Septifer* reacts by drawing itself down into any depression which it may encounter.

Septifer is generally found in the mid-intertidal area where it nestles in nooks and crannies. Where all 3 species of mussels occur together, *Septifer* is to be found right next to the rock face. *Mytilus californianus* is next, on top of *Septifer*, and finally, *M. edulis* occurs on the outside of such a "three species" clump.

If one considers the two extremes of exposure to wave impact to which *Mytilus edulis* and *M. californianus* are separately adapted, the behavioral differences can be correlated with a presumed advantage for each species. In quiet waters, where *M. edulis* predominates, mussel clumps tend to become saturated with fine mud which settles out from the still water. Table 2 records the mean dry weight of silt taken at bi-monthly intervals from cages immersed in Santa Barbara Harbor (heavy silting), and Ellwood Pier (less silt). Plainly it would be advantageous for any individual to be able to crawl above this mud and so avoid being buried.

Table 2

Comparison of the dry weight of silt taken from cages of mussels set at Santa Barbara Harbor and at Ellwood Pier (below low water), at bi-monthly intervals.

	N	Y	S	N	Y	S
1	4	72.13	±43.38	4	6.13	±3.18
2	2	34.80	±22.0	2	6.88	±6.03
3	2	113.40	±55.80	2	8.40	±1.20
4	4	54.45	±14.95	3	3.51	±2.13
5	2	89.75	±4.5	2	7.04	±5.98

N = sample size Y = mean S = standard deviation

[In this connection it may be noted that when small mussels of both species are grown together within cages suspended in the Santa Barbara Harbor, *Mytilus edulis* crawls to the outside of the clumps, leaving *M. californianus* on the inside to be eventually smothered by the accumulating silt.]

On the exposed coast where *Mytilus californianus* predominates, it would perhaps be advantageous to this animal to attach itself quite firmly to the substratum

since any individual crawling to the outside of a clump would presumably run the danger of being washed off. In fact, pure *M. californianus* clumps tend to be very tightly bound up with byssal threads and it is almost impossible to tear chunks of such clumps loose with one's bare hands. In contrast to this, when *M. edulis* forms pure species clusters (i. e., on pilings within harbors), it is possible to tear these clumps apart with little effort. It is as if individuals of *M. edulis* sabotage the structure of the clumps of which they are a part by continually attempting to crawl out on top of each other.

An alternative reason for the marked crawling behavior of *Mytilus edulis* might be that this is a "behavioral character displacement" which has been evolved through competition with *M. californianus* (i. e., individuals of *M. edulis* which become trapped within a clump are soon crushed and only those on the outside of a clump may survive).

To throw some light on the latter hypothesis, I took some *Mytilus edulis* from the East Coast of the U. S. A. (Cape Ann, Massachusetts) where *M. californianus* does not occur, and compared their "crawl-out" behavior with

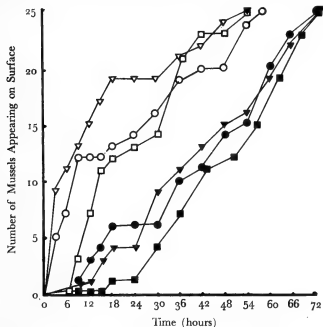


Figure 3

Comparison between the rate of "crawling out" shown by *Mytilus edulis* from the West Coast of North America (Santa Barbara, California) and *Mytilus edulis* from the East Coast of North America (Cape Ann, Massachusetts), when both samples are initially buried under 5 cm of road gravel.

Three replicate runs for each sample are recorded, solid symbols representing West Coast *Mytilus edulis*, open symbols representing East Coast *Mytilus edulis*, with total number of animals used for each trial 25 and the water temperature at 18° C.

that of the West Coast (Santa Barbara) *M. edulis*. The East Coast mussels crawled out from the gravel at a much faster rate than the West Coast mussels (Figure 3). This experiment was repeated in water at temperatures of 12° C and 18° C (the latter was the temperature of Santa Barbara ocean water) with similar results. Since *M. edulis* occurs by itself on the East Coast, it would seem that this behavior might have developed as an adaptation to the physical environment rather than as a response to interspecies competition. If this were so, one could then view "crawling out" behavior as a preadaptation for competitive interaction with *M. californianus*.

DISCUSSION

Crawling behavior of *Mytilus edulis* has been noted by European workers, i. e., FIELD (1922) and MAAS GEESTERANUS (1942). FIELD (*op. cit.*) described the course of several small mussels as they worked their way up an aquarium wall. Movement takes place in the following manner: the mussel extends its foot and at the same time produces a byssal thread which it then fastens by means of the foot-groove and associated glands at the tip of the foot, then releasing its old thread(s) and pulling itself onto the new one. The process is then repeated until journeying is done. This characteristic behavioral trait of *M. edulis* is in itself rather insignificant but it is enough to give the animal a considerable advantage when competing with *M. californianus* (HARGER, 1967). Of course, the position on the outside of a mussel clump is not entirely without danger, as the likelihood of being swept away by waves or taken by some predator is greatly increased (HARGER, *op. cit.*, LANDENBERGER, 1967).

It is possible that it is this "crawling out" behavior which has enabled *Mytilus edulis* to become so widespread throughout the world (see STUBBINGS, 1954, for an account of the distribution). Certainly *M. edulis* is spread widely throughout the Northern and Southern hemispheres and, further, it is known to successfully colonize both rocky shores and muddy bottomed bays (LEWIS, 1953).

It would indeed be interesting to know whether any other species of mussel is as adept at this crawling behavior as *Mytilus edulis*.

SUMMARY

I have shown that a difference in behavior exists between *Mytilus edulis* and *M. californianus* in that the former

species tends to crawl more rapidly out from under objects which press against it, than the latter. A third mussel, *Septifer bifurcatus*, does not show this behavior but rather tends to pull itself down against the substratum.

The crawling behavior ensures that *Mytilus edulis* becomes arranged on the outside of mixed species (*M. californianus* and *M. edulis*) mussel clumps and so enjoys an initial competitive advantage over *M. californianus*. This behavior also insures that *M. edulis* can keep above the surface of mud when it colonizes soft muddy areas (bays, etc.).

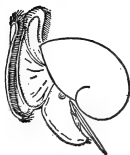
ACKNOWLEDGMENTS

This work forms part of a Ph. D. dissertation submitted at the University of California at Santa Barbara. I wish to thank Dr. J. H. Connell for collections of *Mytilus edulis* made at Cape Ann, Massachusetts, for guidance and for criticism and above all for allowing me to develop ideas under his guidance. I wish also to thank Dr. D. E. Landenberger and Mr. J. Stimson for constant and helpful criticism, and Dr. E. W. Fager for his contribution in the form of a pointed question which led to my discovering that mussels could crawl sideways as well as upwards.

Finally I would like to thank the Signal Oil and Gas Company for making their pier at Ellwood, California, available for ecological research.

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Notes on the Food of *Conus dalli* STEARNS, 1873

BY

JAMES W. NYBAKKEN

Moss Landing Marine Laboratories, Box 223, Moss Landing, California 95039

Conus dalli STEARNS, 1873 HAS LONG BEEN considered to be the West American representative of the *C. textile* group and indeed its color pattern is such that it is difficult to distinguish from its Indo-Pacific congener (HANNA, 1963).

KOHN (1959) has reported that *Conus textile* LINNAEUS, 1758 is a mollusk eater, and it is therefore of interest to know whether or not *C. dalli* shares this dietary preference. To my knowledge the food of this species has not been reported in the literature, a gap which may be due in part to the fact that it is not commonly collected alive. This note reports on observations of *C. dalli* feeding on mollusks.

On November 13, 1967, while I was participating in Stanford University's *Te Vega* Expedition 16¹, four living specimens of *Conus dalli* were collected at Cape San Lucas, Baja California, Mexico, by members of the expedition. These four specimens were all collected in a small area of loose rock on a sand substrate. The depth varied from 5 to 8 feet. All four specimens were found buried in sand under rocks. Specimens of *C. diadema* SOWERBY, 1834, *C. tiaratus* BRODERIP, 1833, and *C. nux* BRODERIP, 1833, were collected at the same time.

I kept the four specimens of *Conus dalli* alive in a small aquarium on the ship. Three days after they were collected I attempted to feed them by introducing a specimen of the gastropod genus *Acanthina* (probably *A. tyrianthina* BERRY, 1957) into the aquarium. After about half an hour, during which time the potential prey made several passes around the aquarium very near to, and sometimes over, the *C. dalli* specimens, the largest cone began to show interest and extruded its proboscis. The proboscis was moved around to the posterior part of the prey, and the animal was stung on the postero-lateral portion of the foot. The *Acanthina* immediately retracted into its shell. The *C. dalli* again probed the aperture area with its proboscis, but I could not determine whether the prey was stung again. The *C. dalli* then rolled the *Acanthina* over with the front of its foot so that the aperture faced upward toward the cone. The front part of the foot remained in place over the

siphonal notch, and again the proboscis made several additional probings of the aperture.

Following the probings, the buccal area expanded over the aperture of the *Acanthina*, obscuring any further observation. This condition prevailed for 27 minutes. At the end of this period the cone withdrew its buccal area but remained in position over the shell of the *Acanthina* for another 4 minutes before moving off.

A check of the shell of the *Acanthina* immediately after the cone had moved off revealed that it was completely empty, the whole animal having been consumed by the cone.

I subsequently brought all four specimens of *Conus dalli* back to my aquaria at Moss Landing, where they were placed together with several other West American *Conus* species.

A few days after introducing the *Conus dalli* into the aquarium I noticed a large number of empty shells of *C. nux*. This sudden increase in mortality of a cone that had theretofore lived well in aquaria led me to suspect that *C. dalli* was preying on *C. nux*. This suspicion was confirmed when I placed one specimen of each of the two cone species in an isolation aquarium. The initial attack was not observed, but the position of the *C. dalli* while feeding on the *C. nux* was similar to that observed for *Acanthina*.

The *Conus dalli* showed a marked preference for *C. nux* over other *Conus* species. *Conus dalli* did not, for example, attack *C. diadema* or *C. tiaratus* of a size similar to that of *C. nux* even though they were left together in aquaria for several weeks. Whether *C. nux* is the normal food of *C. dalli* in the natural environment is not known, but both species were collected together so it would not seem unreasonable to suspect this.

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The Interrelationships of Certain Boreal and Arctic Species

of *Yoldia* MÖLLER, 1842

BY

I. McT. COWAN

University of British Columbia, Vancouver, British Columbia, Canada

(Plate 5; 9 Tables)

MEMBERS OF THE PROTOBRANCH genus *Yoldia* are among the most widely distributed Lamellibranchia in northern oceans. They inhabit mud bottoms to depths of 100 fathoms \pm and may be the most abundant mollusk on them. Their abundance in the stomachs of bottom-feeding fishes suggests that they are an important element in the benthic food chains.

Within this genus there is a group of species characterized by the simultaneous presence of an elongate form with tapered, sub-acute posterior extremity, an approximately central umbo, slender rather than bulbous form, a highly polished cuticle devoid of sculpture or surface pattern of any kind, and with an unstriated resiliifer.

Several names have been applied to members of this group:

Yoldia amygdalca VALENCIENNES, 1846, described from specimens obtained on the cruise of the 'Venus' at Kamchatka.

Yoldia hyperborea (LOVÉN) TORELL, 1859, was described on the basis of specimens from Spitzbergen.

Yoldia limatula gardneri OLDROYD, 1935, from Garden Bay, Pender Harbour, British Columbia.

Yoldia limatula (SAY, 1831) was based upon specimens taken in fish stomachs in Massachusetts waters.

Yoldia norvegica. DAUTZENBERG & FISHER, 1912 regarded the specimens from the coast of Norway as distinctive and applied this name, without designating a holotype.

Yoldia hyperborea limatuloides OCKELMANN, 1954, is the most recent name to appear. The type locality is Fossfjord, N. W. Iceland, but the form is stated to occur also from the Lofoten Islands to eastern Finland.

All have been described from shell characters alone and in only one instance (OCKELMANN) has an attempt

been made to express the observed differences quantitatively. He used 3 shell ratios in an attempt to distinguish *Yoldia limatula*, *Y. sapotilla* and *Y. hyperborea* and found them to be of little use.

One of the problems of developing quantitative expression of difference in the form of the lamellibranch shell is that in most species it grows throughout life. In many species also the shell changes in proportions with growth and thus renders dimensional ratios meaningless. This leaves the possibility that in any comparison of shell dimension between different populations the bias due to age or size may be great.

In the present study I have attempted to avoid this problem by regressing pairs of measurements so as to develop an expression of the relative growth of the different parts of the shell in each apparently distinct population. Analysis of covariance was used in making mathematical comparison between the equivalent regression coefficients of different populations.

In order to develop these criteria my series for measuring were selected to contain the widest possible size range from each locality.

METHODS

Samples from individual geographic locations were given close visual inspection followed, in some cases, by trial comparison of ratios. Where no or almost no differences were apparent, the samples were pooled into composite samples suspected of representing definable entities of possible taxonomic value. Greatest length of the shell has been used as the basis of each regression. While the slope of the regression line is certainly a biologically meaningful expression, the position of the intercept on the Y axis is probably no less a characteristic of the population. Its biological meaning, however, is less apparent.

All statistical procedures were undertaken on a digital computer.

MEASUREMENTS

All measurements were taken with a sliding caliper equipped with a dial vernier. The measurements taken and the symbols employed to designate them on the analytical tables are as follows:

X = The greatest length of a single valve taken in a straight line. Left and right valves were measured in each instance where they were available and intact.

Y1 = The greatest height of the valve from ventral margin to peak of the umbo taken at right angles to the dorsal plane.

Y2 = The length of the pallial sinus measured from the posterior tip of the shell.

Y3 = The anterior length of the valve taken from highest point on the umbo to the most distant point on the anterior margin.

Y4 = The posterior length measured similarly.

Y5 = The number of teeth on the posterior side of the umbo.

Y6 = The number of teeth on the anterior side of the umbo.

Y5 + Y6 = thus the total number of teeth on the hinge line.

The small teeth close to the resilifer were difficult to count on certain large specimens but every effort was made to expose them and count them accurately.

POPULATIONS SELECTED FOR COMPARISON

The selection of populations to be compared statistically is a critical step in the process of exploring for significant differences. I know of no substitute for careful visual inspection of the field samples supported by trial comparison of measurements and this has been the basis of selection used here. It was felt to be important to include for comparison those populations that had been previously described as differing from others, along with those that the present study revealed. Thus the following stocks have been treated separately.

1. The form inhabiting the high Arctic seas around the world.

2. The population of Kamchatka, the southwest Bering Sea and the Sea of Okhotsk.

3. The population from Iceland and the coast of Norway.

4. The population inhabiting the western Atlantic from Nova Scotia to Massachusetts.

5. A small collection from depths of 155 - 285 fathoms in Delgado Canyon, off Cape Mendocino, California. This population appears to be discontinuous from others, both geographically and by depth occupied.

6. The specimens from the coast of Alaska south of the Alaska Peninsula.

7. The many localities represented in Georgia Strait, British Columbia.

8. A sample from Malcolm Island, Queen Charlotte Strait, British Columbia.

9. A sample from Masset Inlet, Queen Charlotte Islands, British Columbia.

At the same time some local variation seemed apparent along the coast of British Columbia where barriers to free dispersion seemed to be few. To explore the nature of variation under these circumstances, 3 populations (7, 8, 9) were included in comparison with specimens from the contiguous areas along the Alaskan coast.

COMPARISONS

Tables 1 to 6 present the results of covariance analysis derived from the regressions obtained from the 9 populations. For purpose of interpretation I have used .01 as the level of significance to which systematic meaning can be attached.

Let us first examine the several samples drawn from the relatively continuous north-south distribution along the coast of British Columbia and southeastern Alaska using the centrally placed Masset Inlet population as a basis of comparison (Table 4). Gross inspection suggests that the specimens from the Strait of Georgia are uniformly deeper for their length than those from the other areas. The only exception from this general condition is found in the small series that served as the type lot for *Yoldia limatula gardneri* OLDROYD. These are proportionately shallower, i. e. more slender than the Strait of Georgia form but can be matched among series from the outer coast of British Columbia and Alaska.

It will be seen that the Queen Charlotte Islands stock is identical with the Malcolm Island stock in all slopes of the regressions and differs in only one intercept feature - that is the posterior length. In comparison with the Georgia Strait stock the regression of width on length is different, confirming the general impression referred to above. Two of the intercept figures are different, the pallial sinus scar and the anterior teeth.

The Queen Charlotte Island sample is identical with the Alaskan sample in all features except length - width relationship. It differs from the California sample in two intercept features only.

Table 1

Probability of Significance of Covariance Analysis of Slopes of *Yoldia "norvegica"*

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. hyperborea</i>	+	—	—	—	+	+	+
<i>Y. amygdalea</i> (K) ¹	—	.1	—	.05-.1	—	—	—
<i>Y. amygdalea</i> , Alaska	—	.1-.2	—	.05	—	—	—
<i>Y. limatula</i> , Atlantic	—	—	—	.01-.025	.05-.1	.01-.025	.025

Probability of Significance of Covariance Analysis of Intercepts of *Yoldia "norvegica"*

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. hyperborea</i>	+	+	+	+	+	+	+
<i>Y. amygdalea</i> (K)	.05-.1	—	+	.01-.025	+	.005-.01	+
<i>Y. amygdalea</i> , Alaska	+	+	.001-.005	.005	.025-.01	.025-.01	.01
<i>Y. limatula</i> , Atlantic	.1-.2	—	+	+	.01	+	+

¹ Kamchatka stock

+ indicates a probability of accidental occurrence < .001

— indicates a probability of accidental occurrence > .1

Table 2

Probability of Significance of Covariance Analysis of Slopes of *Yoldia hyperborea*

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. amygdalea</i> (K)	+	+	.1	.025-.05	+	+	+
<i>Y. amygdalea</i> , Alaska	+	.001	—	.1-.2	+	+	+
<i>Y. limatula</i> , Atlantic	+	.01	.001	.001-.005	+	+	+

Probability of Significance of Covariance Analysis of Intercepts of *Yoldia hyperborea*

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. amygdalea</i> (K)	+	+	+	+	+	+	+
<i>Y. amygdalea</i> , Alaska	+	+	.01-.005	+	+	+	+
<i>Y. limatula</i> , Atlantic	+	+	.1-.2	+	+	+	+

Table 3

Probability of Significance of Covariance Analysis of Slopes of *Yoldia amygdalea* (K)

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. amygdalea</i> , Alaska	—	—	—	—	—	—	—
<i>Y. amygdalea</i> , Georgia Str.	—	—	—	—	—	.05	.1
<i>Y. amygdalea</i> , California	—	—	—	—	.005-.01	+	+

Probability of Significance of Covariance Analysis of Intercepts of *Yoldia amygdalea* (K)

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5 + Y6/x
<i>Y. amygdalea</i> , Alaska	+	+	+	+	.025-.05	.2	.05-.1
<i>Y. amygdalea</i> , Georgia Str.	+	.005-.01	+	+	.05-.1	+	.001-.005
<i>Y. amygdalea</i> , Humboldt	—	+	+	.005-.01	.1	+	.1-.2

Thus along the 1000 ± miles of coastline from the Alaskan Peninsula to the coast of California there is a great uniformity in the measurable features of this *Yoldia*, with significant differences in no more than 2 of 14 po-

tential comparisons for any 2 of the sub-populations that gave rise to the samples. These represent a bathymetric range from 10 fathoms to 200 fathoms. The conclusion reached is that the Pacific Coast is inhabited by

Table 4

Probability of Significance of Covariance Analysis of Slopes of *Yoldia amygdalea*, Masset

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5+Y6/x
<i>Y. amygdalea</i> , Malcolm Isld.	.1- .2	—	.1- .2	.1- .2	—	—	—
<i>Y. amygdalea</i> , Georgia Str.	+	.05- .1	.1- .2	.05- .1	—	—	—
<i>Y. amygdalea</i> , Alaska	.001- .05	.1- .2	—	—	—	—	—
<i>Y. amygdalea</i> , California	.01- .02	—	—	—	—	.1- .15	.2
<i>Y. amygdalea</i> (K)	.005- .01	—	—	—	—	—	—
<i>Y. norvegica</i> , Norway-Iceland.	.025- .05	.005- .01	—	—	—	—	—

Probability of Significance of Covariance Analysis of Intercepts of *Yoldia amygdalea*, Masset

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5+Y6/x
<i>Y. amygdalea</i> , Malcolm Isld.	—	—	.1- .2	.001- .005	.025- .05	.05- .1	.025- .05
<i>Y. amygdalea</i> , Georgia Str.	.025- .5	+	—	—	.1	.001- .005	.01- .025
<i>Y. amygdalea</i> , Alaska	—	—	.025- .05	.1- .2	.1- .2	.05- .1	.05- .1
<i>Y. amygdalea</i> , California	+	—	.1	.001- .005	.2	—	—
<i>Y. amygdalea</i> (K)	+	+	+	+	.2	.05- .1	.1
<i>Y. norvegica</i> , Norway-Iceland.	.001- .005	+	.001- .005	.001- .005	.025- .05	.025	.025- .05

Table 5

Probability of Significance of Covariance Analysis of Slopes of *Yoldia amygdalea* (Bering "Intergrades")

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5+Y6/x
<i>Y. amygdalea</i> (K)	.01- .025	.05	.05	—	.01	.001	.001
<i>Y. hyperborea</i>	—	.1- .2	—	—	.025- .05	.1	.05

Probability of Significance of Covariance Analysis of Intercepts of *Yoldia amygdalea* (Bering "Intergrades")

Compared with	Y1/x	Y2/x	Y3/x	Y4/x	Y5/x	Y6/x	Y5+Y6/x
<i>Y. amygdalea</i> (K)	+	.005- .01	+	.05	.1- .2	—	—
<i>Y. hyperborea</i>	+	.05	+	+	+	+	+

a remarkably uniform stock of this species of *Yoldia*, displaying only minor geographic variation in form and in relative growth features. The most obvious of these variants is that occupying the heavily silted bottoms of the Strait of Georgia and Puget Sound.

Table 6 summarizes the differences appearing in the comparisons of the 14 potential differences in numerical attributes that could occur between each of the stocks analysed. If these are arranged to reveal geographic replacement, the Pacific Coast stock differs from that of the Okhotsk-Kamchatka areas in a total of 5 of the

indices, Kamchatka from the Arctic stock in 12, the Arctic from Norway-Iceland in 11, and from the American Atlantic coast stock in 13. The number of differences appearing between the Norway-Iceland form and the American Atlantic form is 5.

The Arctic form therefore differs from all others with which it is in contact in 11 or more of the 14 features studied here, whereas none of the other stocks, even those separated by the entire extent of the Arctic Seas, and presently occurring in the North Atlantic and North Pacific, differ in more than 5 features when one uses the .01

Explanation of Plate 5

Figure 1: *Yoldia amygdalea*, Sakhalin Island, NW Pacific. × 1.2

Figure 2: *Yoldia amygdalea*, Masset, Queen Charlotte Island, British Columbia × 1

Figure 3: *Yoldia amygdalea*, Strait of Georgia, British Columbia × 1.6

Figure 4: *Yoldia amygdalea*, California Coast

Figure 5: *Yoldia amygdalea*, Iceland × 1.6

Figure 6: *Yoldia hyperborea*, Point Barrow, Alaska × 1.5

Figure 7: *Yoldia hyperborea*, Disco, Greenland × 1.5

Figure 8: *Yoldia limatula*, Eel Pond, Massachusetts × 2

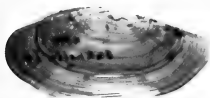


Figure 1

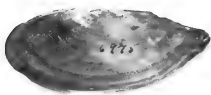


Figure 2

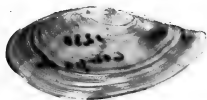


Figure 3



Figure 4



Figure 5

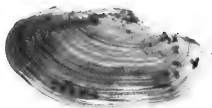


Figure 6



Figure 7

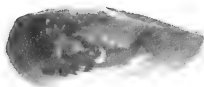


Figure 8

Table 6

Numbers of Features Distinguishing Stocks of *Yoldia*

Comparison	Number of Significant Differences					
	Slope (max. 7)		Intercept (max. 7)		Totals (max. 14)	
	(a)	(b)	(a)	(b)	(a)	(b)
	Significant at .01	Significant at .05	Significant at .01	Significant at .05		
1. Masset : Malcolm Isld.	0	0	1	3	1	3
2. Masset : Georgia Str.	1	1	1	4	2	5
3. Masset : Alaska	1	1	0	1	1	2
4. Masset : California	0	1	2	2	2	3
5. Masset : Kamchatka	1	1	4	4	5	5
6. Masset : Norway-Iceland	1	2	3	6	4	8
7. Arctic : Pacific Coast	5	5	7	7	12	12
8. Arctic : Amer. Atlantic	7	7	6	6	13	13
9. Arctic : Norway-Iceland	4	4	7	7	11	11
10. Arctic : Kamchatka	5	6	7	7	12	13
11. Kamchatka : Norway-Iceland	0	1	4	5	4	6
12. Norway-Iceland : American Atlantic	0	3	5	5	5	8

level of probability as the criterion of significance. The .05 level of significance does not alter the situation respecting the Arctic population. It is clearly a very different stock. This level, however, reveals the Georgia Strait stock as having more distinctive features than the other samples drawn from the NE Pacific. It also increases the apparent difference between the Norwegian and the American Atlantic stocks.

Returning to the differences at the .01 level (total "a" of Table 6), and comparing geographically contiguous stocks, it is possible to suggest that 3 clearly differentiable stocks exist: (1) that inhabiting the NE Pacific Ocean, the Sea of Okhotsk, the coast of Kamchatka and the southern Bering Sea; (2) the Arctic Seas of both hemispheres; and (3) the shallow waters of the North Atlantic Ocean including Iceland and the coast of Norway. The American Atlantic stock differs from Arctic and Pacific stocks to a similar degree.

The data derived from the covariance analysis of regressions and intercepts reveals the numbers of criteria by which the several stocks differ from one another but tell us little about the nature or direction of the differences. These details can be derived from inspection of the specimens and from the conventional measurements. They do not alter the conclusions to be reached from the present analysis.

Specimens originally from Iceland and the coast of Norway are remarkably similar in general appearance to the specimens taken along the Pacific coast of North America. In fact, the characteristics by which they each differ from the Arctic population (Tables 1-4) are in

general the same. One might ask, therefore, are they indeed the same organisms separated into the North Atlantic and North Pacific stocks by an inhospitable area of Arctic environment occupied by another form.

A direct comparison between the North Pacific and North Atlantic stocks reveals that, at the .01 level of significance, they do not differ in any of the 7 regressions (Tables 1 & 4), but do so in 4-6 of the intercepts, depending upon which Pacific Coast sample is used in the comparison. Clearly then, the differences between the stocks of the two oceans is greater than the differences between any two of the samples from the Pacific coast of North America.

The relationship between the North Atlantic stock and that of the American Atlantic is also interesting. As OCKELMANN (1954) pointed out, there are distinct and consistent differences in the shape of the shell between these two stocks. The American Atlantic specimens lack the anterior and posterior indentations in the ventral margin of the shell. There are differences also in the shape of the siphonal muscle scar. My data suggest two features of shell proportion and dentition ($p < .025$) and 5 intercept characteristics that distinguish the two Atlantic stocks.

The general form of the North Atlantic specimens suggests that they might be the outcome of intergradation between the Arctic form and that of the American Atlantic. Their geographic situation and the absence of any substantial evidence of intergradation along the coasts of Newfoundland and Labrador leave us with no evidence to support such an explanation. I have seen no

series of *Yoldia* from Newfoundland and Labrador, so future collections may require a re-examination of the relationships between the 3 forms encroaching upon the North Atlantic.

TAXONOMIC CONSIDERATIONS

It has been shown that there are few differences between several stocks of *Yoldia* separated widely along the Pacific coast of North America. It has also been shown that these do not differ substantially from the form inhabiting the Sea of Okhotsk and the Kamchatka coast. The first available name for this stock is *Yoldia amygdalea* VALENCIENNES, 1846.

The name *gardneri* OLDROYD, 1935, applied to a supposed subspecies of *Yoldia limatula* (now *Y. amygdalea*) in the northern part of the Strait of Georgia, British Columbia, appears to be without foundation. It referred to unusually slender examples that occur among the normal population.

Yoldia hyperborea (LOVÉN) TORELL, 1859 is the accepted name applicable to the distinctive and remarkably uniform stock of Arctic Seas.

In my opinion, the characteristics of the stock from the North American coast of the Atlantic, taken with the absence of certain evidence of intergradation with *Yoldia hyperborea* to the north argue for recognizing this as a separate species under the name *Y. limatula* (SAY, 1831), that has been used for this form for more than a century.

OCKELMANN (1954) regarded the form of the North Atlantic as a subspecies of *Yoldia hyperborea* and applied the name *limatuloides* to it. It has now been shown that this population differs as profoundly from *Y. hyperborea* as any of the other stocks compared. The weight of evidence now suggests that this stock be regarded as conspecific with *Y. amygdalea* and that this species, as is the case with *Y. myalis*, is now divided into Atlantic and Pacific stocks differing but little from one another. If a subspecies designation be regarded as useful, the name *Y. norvegica* DAUTZENBERG & FISCHER, 1912, though not described with a designated type specimen, was clearly applied to the form of the Norwegian coast and has priority over *limatuloides* of OCKELMANN. This author regarded *Y. norvegica* as a synonym of *Y. hyperborea*, but the geographic reference by DAUTZENBERG & FISCHER seems to deny this. In this instance there seems to be no need for a separate designation for this stock.

It is pertinent to ask whether there is any strong evidence of intergradation between stocks I have defined as possessing characteristics suggesting clear cut differences. Thirteen specimens from the eastern Bering Sea

(St. Matthews Island, Nunivak Island, N of Unimak Island, near Pribiloff Islands) originate from an area where intergradation between *Yoldia hyperborea* and *Y. amygdalea* might be expected to occur. They do indeed show characteristics of form apparently intermediate in some degree. Table 5 presents the probabilities of significance of covariance analyses comparing the possible intergrades with both the putative parent stocks. While *Y. amygdalea* differs from *Y. hyperborea* in 12 criteria, it differs from the supposed intermediates in 5 and *Y. hyperborea* differs from them in 6. The differences are in the expected direction.

On the strength of these comparisons, and others involving unmeasurable aspects of shell form there seems to be evidence that these specimens are indeed intermediates between the Arctic and North Pacific-Kamchatka forms. The question then arises as to the interpretation to be placed upon this intergradation. It could be regarded as evidence that complete introgression is possible and that the two populations should be regarded as subspecific expressions of a single wide ranging species.

In the genus *Yoldia*, *Y. myalis* and *Y. thraciaeformis* both occur in twin populations occupying the North Pacific and North Atlantic and separated by the Holarctic region in which they do not now occur. In this study evidence is produced to reveal *Y. amygdalea* as similarly distributed. The first two species named have no surviving close relative in Arctic waters. One can conclude, therefore, that they previously occupied Arctic waters but have been exterminated in them so recently that little or no morphological difference has developed between the relict populations. The failure of the Arctic stocks may well have occurred during the closure of Bering Straits, with the considerable alteration in the circulation of Arctic waters and possibly of local mid water habitats. A possible alternative explanation would involve continuity of distribution through tropical waters at a time when the two Americas were separate. This seems less likely.

In the case of *Yoldia amygdalea* rather than extermination, evolutionary change gave rise to a form adapted to arctic conditions (*Y. hyperborea*). The evidence of the samples now available from the southern Bering Sea suggest that genetic isolation between the two species is incomplete. It seems to me, however, that the existence of the North Atlantic stock of *Y. amygdalea*, the very extensive range of this species in the Pacific, the extent of the area occupied by *Y. hyperborea* in the Arctic, and the absence of any evidence of intergradation between it and the Atlantic *Y. amygdalea* all point to species status as best expressing the relationship between *Y. hyperborea* and *Y. amygdalea* despite the evidence of some introgression over a narrow area of contact in the Bering Sea.

Table 7

Regression Formulae for *Yoldia amygdalea*

<i>Yoldia amygdalea</i> (British Columbia & Alaska)								
N = 76	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9896	.9896	.9959	.9949	.9016	.8821	.9867	.8821
Slope of Regression	.4085	.5248	.5252	.5331	.9567	1.2466	1.0025	1.2466
Intercept	1.0274	-.2126	.6928	-.6860	8.7841	12.4484	-1.2110	12.4485
<i>Yoldia amygdalea</i> (Kamchatka)								
N = 39	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9749	.9575	.9765	.9815	.8773	.3167	.9316	.8672
Slope of Regression	.4239	.5359	.5146	.5418	.3908	.2977	.9759	1.1894
Intercept	1.5869	-1.7885	2.3090	-1.7059	8.5078	19.0575	-2.4483	3.5084
<i>Yoldia amygdalea</i> (Iceland & Norway)								
N = 22	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9855	.9601	.9795	.9842	.7486	.8453	.9547	.9224
Slope of Regression	.4250	.4476	.5329	.4819	.4164	.5777	.8566	1.1334
Intercept	1.2303	1.0776	.7688	.7797	10.0510	11.8195	.8456	3.4409
<i>Yoldia amygdalea</i> (California)								
N = 27	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9675	.9048	.9594	.9898	.3466	.1850	.9482	.5634
Slope of Regression	.4488	.5059	.5030	.5469	.1551	.2714	.9992	.5672
Intercept	.5167	.7929	1.4659	-1.4475	1.9588	18.6113	-.9333	16.8931

Table 8

Regression Formulae for *Yoldia hyperborea*

N = 107	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9935	.9906	.9835	.9848	.8445	.8384	.9465	.9582
Slope of Regression	.4898	.4444	.5686	.4882	.3867	.4336	.8114	1.0750
Intercept	.5602	.3732	-1.4579	2.2097	10.2074	13.9943	4.1348	3.1618

Table 9

Regression Formulae for *Yoldia limatula*

N = 48	x/Y1	x/Y2	x/Y3	x/Y4	x/Y5	x/Y6	Y3/Y4	Y5/Y6
Correlation between	.9964	.9965	.9990	.9985	.9102	.9037	.9967	.9674
Slope of Regression	.4430	.4692	.5229	.5268	.2799	.3431	1.0046	1.1942
Intercept	.4979	.4674	.4598	-.0071	12.3751	15.0194	-.1296	.5069

Résumé of Species

Yoldia amygdalea VALENCIENNES, 1846 (Plate 5, Figures 1-5)

Type locality: Kamchatka.

Original description: VALENCIENNES, A. Mollusques (in) ABEL DU PETIT-THOUARS. 1846. Voyage autour du monde de la Frégate *Venus*. pl. 23, fig. 6.

Selected Synonymy:

Y. amygdala [sic] REEVE, 1873. Conchologia Iconica 18: pl. 1, figs. 3a, 3b.

Y. limatula (pars) DALL, 1921. U. S. Nat. Mus. Bull. 112: 13 (and elsewhere)

(pars) LA ROCQUE, A., 1953. Nat. Mus. Canada 1953: 25; OLDROYD, I. S., 1924. Stanford Univ. Publ. Geol. Sci.

Y. gardneri OLDROYD, 1935. Nautilus 49: 14 (Type locality: Garden Bay, Pender Harbour, Vancouver Island, B. C.)

Y. norvegica DAUTZENBERG & FISCHER, 1912. Résultats des campagnes scientifiques ... par Albert I, Prince Souverain de Monaco. Fasc. 37: 403 (Type locality: Norway).

Y. hyperborea limatuloides OCKELMANN, 1954. Medd. om Grønland 107 (7): 11 (Type locality: Fossfjord. N. W. Iceland).

Distribution: This is the species from the Okhotsk Sea and Kamchatka and from the Pacific Coast of North America, south of the Bering Sea into Northern California. The Atlantic stock occupies both coasts but comes north to Iceland but not Greenland. South further in the west than in the east. Specimens examined from:

USSR: Avancha Bay; Plover Bay; Kamchatka coast at 55°57'N, 162°20'E; Okhotsk Sea at 52°43'N, 155°41'E; Aniva Bay, South Sakhalin Island.

NE Pacific: Alaska: Redfish Bay, Stikine Delta; St. Matthews Is.; Nunivak Is.; N of Unimak Is.; near Pribiloff Islands.

British Columbia: Masset, Queen Charlotte Island; Malcolin Island; Smith Inlet; Beaver Harbour; Okeover Arm; Tofino Inlet; Barclay Sound; Georgia Strait (many localities).

Washington: off San Juan Island.

California: Delgado Canyon off Buck Creek, Mendocino County.

I have seen no specimens from Oregon or from the outer coast of Washington.

Iceland: Fossfjord.

Norway: Lofoten Islands; Bergen; Ramsfjord; Vadso.

Western Atlantic: 40°29'N, 70°46'W; Bedford Basin; N of

Sable Island, Nova Scotia; Bradilla in Gulf of St. Lawrence; Grand Manan Island; off Halifax, Nova Scotia.

Yoldia hyperborea (LOVÉN) TORELL, 1859. (Plate 5, Figures 6, 7)

Type locality: Spitzbergen.

Original description: TORELL, O. 1859. Bidrag till Spitzbergens Molluskenfauna. Stockholm, pp. 149-150; pl. 2, figs. 6a, 6b.

Selected Synonymy:

Yoldia arctica M. SARS, 1851. Nyt Maf. f. Naturv., 6 (2). Kristiania.

Nucula sapotilla REEVE, 1855 (non GOULD, 1841) (in) BELCHER, E., The last of Arctic voyages. vol. 2, London.

Yoldia limatula G. O. SARS, 1878. Mollusca regionis arcticae Norvegiae, Christiania.

Yoldia glacialis GRAY, 1828, LA ROCQUE, 1953. Nat. Mus. Canada, Bull. 129.

Distribution: Believed to be circumboreal in the Arctic basin, but I have seen no specimens, nor published records of occurrence, from the North American Arctic east of Point Barrow and west of Foxe Basin; nor from the Siberian Arctic east of Novaya Zemlya.

Specimens examined from:

Spitzbergen (several localities); Novaya Zemlya; Disco, Greenland; West Coast Greenland; Foxe Basin; Hudson Bay; and many stations in Canadian Eastern Arctic; Point Barrow, Alaska. OCKELMANN (1954) cites specimens from the Murman coast and the Kara Sea.

Yoldia limatula SAY, 1831. (Plate 5, Figure 8)

Type locality: Nahant, Massachusetts.

Original description: SAY, R. 1831. American Conchology, pt. 2, pl. 12, 3 figs.

Distribution: The North American coast from Nova Scotia to North Carolina. Specimens examined from:

Halifax, Nova Scotia; Sand Island, New Brunswick; Casco and Frenchman's Bay, Maine; Woods Hole, Massachusetts; Newport, Rhode Island; Rariton Bay, New Jersey; Cape Hatteras, North Carolina.

I have seen two specimens from close to Halifax that suggest that intergradation may occur between *Yoldia limatula* and *Y. amygdalea*. However, the evidence is too meager to interpret.



Notes on *Cryptochiton stelleri* (MIDDENDORFF, 1846)

BY

G. E. MACGINITIE

AND

NETTIE MACGINITIE

Route 1, Box 93A, Friday Harbor, Washington 98250

(Plate 6)

FOR QUITE A NUMBER OF YEARS, we have been intrigued by the fact that the giant chiton *Cryptochiton stelleri* is almost invariably free of epibiotic growths. As we have emphasized (MACGINITIE & MACGINITIE, 1968), there are nearly always exceptions to any generalization, so it is not surprising that the defense mechanism of the chiton is occasionally damaged or fails to function. On rare occasions, a barnacle, a tuft of seaweed, or a tunicate may be found growing on the giant chiton. These exceptions are no doubt due to some injury sustained from a rolling rock or floating debris or other abrasive causes.

The present study was begun in an attempt to determine the means by which *Cryptochiton stelleri* keeps its surface free of epibiotic growth. In order to do this, it was first necessary to learn something of the food and habits of the animal so that a number of them could be maintained in aquaria in as healthy and normal conditions as possible.

FOOD AND HABITS

This chiton species is found from low tidal exposures down to a depth of 50 or 60 feet or possibly deeper. Its range is from San Nicolas Island to Alaska and across to Japan. It is most abundant in the northern part of its range. Because its food consists mainly of *Ulva*, *Monostrema*, *Iridia*, or other thin-fronded algae, it may be found where such growth is abundant. We have kept specimens in our laboratory for more than a year and tried them with different types of seaweed, but they show a decided preference for *Ulva* and *Monostrema*. We have withheld food until they were hungry enough to eat, very sparingly, some heavier types of seaweed, even including the stipe of *Nereocystis*. However, they are able to go for months without food of any kind. Examin-

ation of the fecal material reveals that the heavier types of seaweed pass through with little apparent digestion. Even some of the preferred sea weeds, such as *Ulva*, pass through in larger pieces than one would expect.

These giant chitons are extremely slow-moving creatures and move very short distances, say a few inches, in a night when browsing. Those we have kept in aquaria seem to be strictly nocturnal. Very rarely does one move about during the day. Two that we have kept in an aquarium at temperatures ranging from 3°C to 5 or 6°C ceased all visible activity while the temperature remained this low. As most of the seaweeds are annuals, we doubt that even in their natural environment these chitons feed to any extent during the winter months.

Although the chitons of this species reject plants or animals that might adhere to their dorsal surface, they do have commensals. A scale worm *Arctonoe vittata* (GRUBE, 1855) and a pinnotherid crab *Opisthopus transversus* RATHBUN, 1893, are often found in the gill chamber, usually singly, but occasionally together.

GROWTH AND AGE

Cryptochiton stelleri is the largest chiton in the world. Specimens 330 mm (13 inches) long have been recorded. The largest specimen we used was 240 mm long by 115 mm wide. It was about 32 mm high at the highest point. The smallest was 95 mm by 60 mm.

This species grows very slowly. From a count of growth lines on the dorsal valves, it appears that any *Cryptochiton stelleri* that is 7 or 8 inches long or longer is at least 20 years old. On most of the valves, the growth lines die out and become obscure about two thirds of the way in from the outer edge. We have counted the growth

lines on many valves that showed up to 18 or 20 lines and we concluded that such specimens were more than 25 years old. We have not checked the reproduction carefully, but the lines of growth and habits of the animal indicate that it spawns but once a year. Small juvenile specimens are seldom found. This scarcity of young is typical of marine invertebrates that live a long time.

MECHANISM FOR KEEPING CLEAN

We believe we have found the answer to how *Cryptochiton stelleri* keeps so free of epibiotic growth. To understand how this is accomplished, one must know something about the structure of the dorsal integument. The entire dorsal surface of the animal is covered with tufts of fine spicules of calcium carbonate (Plate 6, Figures 2 and 3). Sometimes these tufts, as well as the integument, are a dark brick red over the entire surface but in some specimens the surface is mottled by patches of grayish tufts of spicules. The tufts of spicules terminate abruptly at the edge of the dorsal surface where the integument turns under to form the under side. The number of spicules per tuft varies from about 25 to 365 or over. On a specimen 217 mm long, the number of tufts per square centimeter was fairly uniform, averaging 118 tufts. These tufts of spicules may stand erect in tight vertical columns or they may spread out more or less in the form of rosettes. The individual spicules are 1 mm long or somewhat longer. They are individually controlled, so that some of the spicules in a tuft may stand erect while the others spread out.

A tuft of spicules originates as a bulbous structure within the integument, with a small opening to the surface, and gradually evaginates until it becomes only a depression on the surface with a full bloom of spicules (Plate 6, Figure 1). The bulbous structure is lined with cells, each of which secretes a spicule. When a tuft of spicules is at the surface and functional, each spicule is controlled by a cell at the base.

Our first reaction was to suppose that these tufts spread into rosettes to prevent the settling of larvae on the integument, but quite the reverse is true. The introduction of fine planktonic material to the surface of the chiton causes the tufts of spicules that are spread in rosettes to become erected into columns. Further study revealed that these columns of spicules were supporting a sheet of mucus.

We have never found a dye that will stain secreted mucus. It is possible to stain preserved mucous cells, but not fresh mucus itself. It is impossible to demonstrate mucous layers by any means except by the introduction of finely divided material. To show the presence of mucus, we have nearly always used detritus (MACGINITIE & MACGINITIE, 1968, p. 11) because it does not in any way irritate the secreting animal.

Stained sections of the integument show that mucous glands are abundant and open to the surface in the areas between the tufts of spicules. Though there are no tufts of spicules on the under side, mucous secreting cells continue to be present in that portion of the integument that turns under at the edge. With secretions from the mucous glands, *Cryptochiton* is rapidly able to cover its dorsal surface with a sheet of mucus from 1 to 2 mm thick. As is well known, when mucus comes in contact with water, it quickly swells. As has been shown before (MACGINITIE, 1945), mucus, at least as it is used by several invertebrate animals (MACGINITIE & MACGINITIE, 1968, pp. 186, 203, 336), will prevent the passage of anything larger than 40 Å. Although mucus allows water to flow through it almost unimpeded, it will prevent the passage through it of any larvae, algal spores, bacteria, or viruses – or even molecules with a molecular weight of 160 000 or larger.

By placing some detritus or fine planktonic material on the surface of *Cryptochiton*, the presence of mucus is easily observed. We were unable to determine whether the stimulus of a settling larva causes secretion of mucus only in that local area or whether the mucus covers more of the surface of the chiton. Evidence points to a progressive weakening of the mucous secretion in specimens

Explanation of Plate 6

Cryptochiton stelleri (MIDDENDORFF, 1846)

Figure 1: Section through the dorsal integument; $\times 60$. The irregular diagonal line is the upper surface of the integument. Lower left: developing tuft of spicules. Upper center: mucus secreting glands. Upper right: section through depression where a tuft of spicules is attached. At the base of each spicule is a cell that

regulates the position of the spicule.

Figure 2: View of portion of dorsal surface, showing tufts of spicules; $\times 2$.

Figure 3: Same as Figure 2; $\times 4$. Note that the tufts of spicules are spread into rosettes.

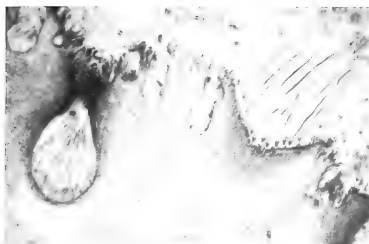


Figure 1

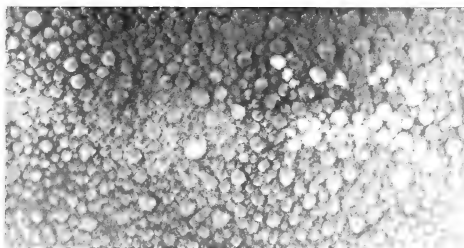


Figure 2



Figure 3

of *Cryptochiton* the longer they are kept in aquaria. In specimens that have been kept in tanks 3 or 4 months or longer, we have found as many as 6 different organisms among the spicules, although they were not attached to the integument.

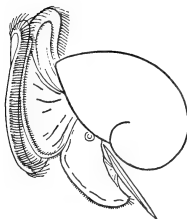
One of the functions of the spicules is to hold the sheet of mucus in place. The invasion of the surface by foreign material stimulates the animal to secrete and discharge mucus and draw the spicules together into columns. However, most of the time, the tufts are spread in the form of rosettes (Plate 6, Figure 3), which undoubtedly is a sort of passive way of excluding larger larvae and tiny animals from its surface. There is no indication that a toxic substance is secreted, for larvae that are introduced onto the sheet of mucus do not respond as they would to a toxic material. They continue to struggle for a much longer time than they would if affected by a toxin. The surface of the sheet of mucus gradually disintegrates and the entrapped organic material is carried away by currents in the water.

ACKNOWLEDGMENTS

We are grateful to the personnel of the Friday Harbor Laboratories of the University of Washington for several courtesies. Through Dr. Paul Illg, we were able to use for study and photographic purposes the excellent slides of the integument (Plate 6, Figure 1) of *Cryptochiton stelleri* made by Deborah L. Christensen, microtechnician at the University of Washington, Seattle. We also wish to thank SCUBA divers Rich Bettger and Jerry Brown of Everett, Washington, for obtaining specimens for us.

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Further Observations on the West American Marginellidae With the Descriptions of Two New Species

BY

BARRY ROTH

1217 Waller Street, San Francisco, California 94117

AND

EUGENE COAN

Department of Biological Sciences, Stanford University, Stanford, California 94305

(Plate 7; 2 Text figures; 1 Map)

IN OUR ACCOUNT of the west American Marginellidae (COAN & ROTH, 1966), we stated that with further work on the family, especially the examination of more specimens, our ideas would probably change. In addition, we felt certain that the article would arouse interest among workers, both to study the material they had on hand and to collect additional specimens. Both anticipations have proved correct. We have accumulated comments adding to and correcting our published account. It seems appropriate to make the new information available at this time.

1. *Marginella (Prunum) sapotilla* HINDS, 1844

(Plate 7, Figures 1, 2)

COAN & ROTH, 1966: 279-280; plt. 48, figs. 1-3; text fig. 1

Photographs of the lectotype of *Marginella evax* LI, 1930, are presented on the Plate. The synonymy of *M. evax* and *M. (P.) sapotilla* remains certain. Because LI's photograph was poor and because his article is not readily available, illustrations of this lectotype are included here.

In addition we are able to refine the distributional information. The species has been found from Bahía Honda, Panama, to Bella Vista, Panama, and as far off the mainland as Isla Pedro Gonzales in the Bay of Panama. Ecuadorian records remain uncertain. PARKER (1964) reported it from the Gulf of California. His specimen is in the Museum of Comparative Zoology at Harvard University and proves to be a young *Olivella*.

2. *Marginella (Prunum) albuminosa* DALL, 1919

(Plate 7, Figures 3, 4)

COAN & ROTH, 1966: 281-282; plt. 48, fig. 11

Records and correspondence in the Division of Mollusks at the United States National Museum indicate that Dr. Alfred Dugés sent the unique specimen, along with other material, to Dall in 1895, and that Dall initially identified it as *Marginella (Prunum) curta* SOWERBY, 1832. There is some indication that Dugés' shipment may have been poorly packed and have arrived at the USNM somewhat mixed. Thus there is additional reason to doubt the occurrence of this species in the west American fauna. Correspondence in the USNM files suggests that Dugés may also have sent some of his material to the Paris Museum, but a search there prompted by our inquiry turned up nothing. We have not yet located other specimens of this species from any province in any museum.

STANTON (1966) reported a specimen of *Marginella (Prunum)* from the Castaic Formation (Upper Miocene) of Los Angeles County, California, as "*Marginella cf. M. albuminosa* DALL." This is a new geologic record for the family and genus in northwest America. STANTON's species will probably require a name of its own in light of the continuing doubt about Dugés' type specimen.

Two better photographs of the holotype of *Marginella albuminosa* are provided here.

3. *Persicula porcellana* (Gmelin, 1791)

(Plate 7, Figures 5, 6)

COAN & ROTH, 1966: 282-283 (pars); pl. 48, figs. 12-15;
non *ibid.*: pl. 48, figs. 16-17

In our earlier article we designated one of the specimens therein illustrated (pl. 48, figs. 14, 15) "lectotype" of *Marginella tessellata* LAMARCK, 1822 - a mistake, since, as the only specimen in the Lamarckian collection, it is assuredly the holotype. At the same time we designated the identical specimen neotype of Gmelin's *Voluta porcellana* - the specimen figured by Chemnitz (1788: pl. 150, figs. 1419, 1420), on which Gmelin based his species, having been lost. We hoped to stabilize nomenclature by this step, which we took after consultation with several other malacologists. At the time of that writing we had examined many west American specimens, but no Caribbean ones. Now we have seen, from the Caribbean, specimens that look like LAMARCK's type and still others which closely resemble the original Chemnitz figures. Some species of *Persicula* are morphologically consistent; others show considerable variation even within local populations (COAN & ROTH, 1966: pp. 284-285). We suspect that there is only one, somewhat variable species in the Caribbean. In light of the Caribbean specimens, there is much less doubt what form Chemnitz had; in the absence of serious doubt, our neotype designation seems superfluous. Since it helps stabilize the nomenclature, however, and since its retraction could cause needless additional confusion, we intend to let the designation stand.

Lamarck's holotype of *Marginella tessellata* is illustrated here with two better photographs. It is without locality data, but most likely came from the Caribbean, considering the early date of Lamarck's publication. *Voluta porcellana* was incorrectly stated by Gmelin to have come from the Indian Ocean.

While the Atlantic species retains the name *Persicula porcellana*, the Pacific species, isolated from it since the Pliocene by the Isthmus of Panama, requires a new name as follows:

Persicula accola ROTH & COAN, spec. nov.

(Plate 7, Figures 7, 8 - Holotype)

Persicula porcellana (Gmelin), COAN & ROTH, 1966: 282-283 (pars); pl. 48, figs. 16-17; non Gmelin, 1791: 3449 (species 139)

Description of Holotype: Shell of moderate size, solid; elongate-ovate, narrower anteriorly; pale yellowish-tan, with about 10 spiral rows of dark reddish-brown, more or less rectangular blotches which show a tendency toward doubling with maturity; entirely covered with a

thin glaze of translucent whitish enamel; outer lip thickened, finely denticulate, white, tinged with brown along outer edge; inner lip covered by a pad of white callus; spire low, covered with clear enamel, circled by a solid brown band; aperture even, slightly wider anteriorly, white within; anterior canal deep, oblique; columella with 7 folds, second fold from anterior end widest, most anterior fold at base of columella.

Dimensions of Holotype: Length 13 mm; width 8.2 mm.

Paratypes: Of the 3 paratypes, 2 are worn mature specimens and 1 is a live-collected, sub-mature specimen with a sharp, uncallosed outer lip. All 3 differ very slightly from the holotype in arrangement of the rows of brown blotches.

Dimensions of Paratypes:

1: Length 12.5 mm; width 7.5 mm (live)

2: Length 13.3 mm; width 8.2 mm

3: Length 12.2 mm; width 7.2 mm

Type Locality: Isla Coiba, Panama (about 7°30' N by 81°45' W); collected by A. Mendez.

Discussion: The pattern of rows of rectangular blotches distinguishes *Persicula accola* from all other west American species of the genus. A key to the west American species (in which this species is identified as "*Persicula porcellana*") appears in COAN & ROTH, 1966, p. 278.

This species is morphologically very similar to its Caribbean analogue, *Persicula porcellana* (Gmelin). Although museums contain only a few lots of each species from which to make comparisons, some minor differences have been noted. First, the west American species is broadest much posterior to the middle of the body whorl, while the Caribbean one tends to be more nearly ellipsoidal. *Persicula porcellana* tends also to be more obese. Second, as in the Chemnitz figures mentioned above, *P. porcellana* may have smaller spots, especially in the northern part of its range - Honduras, Panama, Venezuela. Brazilian specimens have larger spots. *Persicula accola* has, in general, larger, squarer spots. Third, the posterior end of the outer lip of the Caribbean species tends to be produced slightly more than that of the west American form.

Etymology: The specific name derives from the Latin noun for "neighbor."

Material Examined and Range: This species has evidently been collected only 4 times, and 2 of these lots have been divided among several museums. The recorded localities are Isla Coiba, Isla Jicarón, and Bahía Montijo, all in roughly the same area of Panama.

Deposition of Types: Holotype: USNM 513647; Paratypes (3): USNM 665526.

4. *Persicula bandera* COAN & ROTH, 1965

COAN & ROTH, 1965: 67-69; pl. 12, figs. 1-5

COAN & ROTH, 1966: 285; pl. 50, figs. 38, 39

When first describing *Persicula bandera*, we compared it to the closely related *P. hilli* (SMITH, 1950), but not to any species from the Atlantic. We have recently obtained a photograph of the holotype of *Marginella multilineata* SOWERBY, 1846 from the British Museum (Natural History) (Plate 7, Figures 9, 10); that species is a *Persicula*, very similar to *P. bandera*.

Marginella multilineata was described from a specimen in the Cuming collection, picked up by a Mr. Dyson at "Belize [sic], Bay of Honduras." Belize, British Honduras, and the Gulf of Honduras are on the Atlantic coast of Central America; and other Dyson-collected material from "Honduras" has proven to be Atlantic, so there is no reason to doubt the Caribbean locality. REEVE (1865) compared *M. multilineata* to *M. interrupta* LAMARCK, 1822 (= *Persicula interruptolineata* [MEGERLE VON MÜHLFELD, 1816]), a variable Caribbean and west African species; and TOMLIN (1917) incorrectly synonymized the two.

It seems plausible that, as with so many other marginellids, analogous Atlantic and Pacific species are involved. If it ever were to be shown conclusively that Dyson's shell came from the Pacific side of Central America, the name *Persicula bandera* would become a synonym of *P. multilineata* (SOWERBY, 1846).

5. *Persicula hilli* (SMITH, 1950)

(Plate 7, Figures 11, 12)

COAN & ROTH, 1966: 285; pl. 50, figs. 40, 41

At the time of our earlier review, we were unable to locate the type specimens of this species. Through the

courtesy of Dr. Herbert T. Boschung, we have been loaned the type lot from the Maxwell Smith collection in the Museum of Natural History at the University of Alabama at Tuscaloosa. The type lot consists of 4 specimens. SMITH (1950: pl. 4, fig. 6) figured 2 of these. We hereby designate as lectotype the specimen we have illustrated here — the specimen which SMITH figured in ventral view — leaving 3 paralectotypes. The lectotype measures 14.7 mm in length and 9.7 mm in width. SMITH's figured paralectotype is 14.5 mm long and 9.2 mm wide.

6. *Volvarina* sp., cf. *V. taeniolata* MÖRCH, 1860

Among uncatalogued material at Stanford University, we have seen one immature specimen belonging to the genus *Volvarina*, collected at Salinas, Ecuador, in 1951 by Dr. Donald L. Frizzell. This specimen extends the known west American range of the genus to South America. Adult specimens will have to be studied to determine whether this is Mörch's species.

7. *Cystiscus politulus* (DALL, 1919)

(Plate 7, Figures 13, 14; Map)

COAN & ROTH, 1966: 290-291; pl. 51, fig. 64

Hyalina myrmecoon DALL, 1919: 308

Cystiscus myrmecoon (DALL), COAN & ROTH, 1966: 291; pl. 51, fig. 65

Examination of additional material now leads us to synonymize these two species. Since both of DALL's names date from the same article, we are acting as "first

Explanation of Plate 7

Figures 1, 2: *Marginella (Prunum) sapotilla* HINDS, 1844. Lectotype of *Marginella evax* LI, Columbia Univ. Paleo. Coll. 22118; Panama Bay, $\times 2.1$ (ventral and dorsal views)
 Figures 3, 4: *Marginella (Prunum) aluminosa* DALL, 1919. Holotype, USNM 10168, "West Mexico," $\times 1.5$ (ventral and dorsal views)
 Figures 5, 6: *Persicula porcellana* (GMELIN, 1791). Neotype of *Voluta porcellana* GMELIN and holotype of *Marginella tessellata* LAMARCK, Mus. Hist. Nat. Geneva, no locality given; $\times 2.1$ (ventral and dorsal views). Photographs courtesy of Dr. E. Binder
 Figures 7, 8: *Persicula accola* ROTH & COAN, spec. nov. Holotype, USNM 513647, Isla Coiba, Panama, $\times 3$ (ventral and dorsal views)
 Figures 9, 10: *Persicula multilineata* (SOWERBY, 1846). Holotype, British Museum (Natural History), Cuming Coll., "Belize, Bay of Honduras," $\times 3$ (ventral and dorsal views). Photographs courtesy of and © by British Museum (Natural History)
 Figures 11, 12: *Persicula hilli* (SMITH, 1950). Lectotype, Univ. Alabama, Maxwell Smith Coll. 15374, Bahía Chamaela, Jalisco, Mexico, $\times 2.6$ (ventral and dorsal views)

Figures 13, 14: *Cystiscus politulus* (DALL, 1919). Hypotype, USNM 268953, Bahía Magdalena, Baja California Sur, Mexico, 25 m, $\times 9$ (ventral and dorsal views)
 Figure 15: *Cystiscus jewettii* (CARPENTER, 1857). Hypotype, SU PTC 9943, Punta Abrejos, Baja California Sur, Mexico, $\times 8.8$ (ventral view)
 Figure 16: *Cystiscus jewettii*. Hypotype, CASGTC 13107, Point Pinos, Monterey County, California, $\times 8.8$ (ventral view)
 Figures 17, 18: *Cystiscus palantirulus* ROTH & COAN, spec. nov. Holotype, AMNH 128732, Los Frailes Bay, Baja California Sur, Mexico, 37-73 m, $\times 8.8$ (ventral and dorsal views)
 Figure 19: *Kogonea polita* (CARPENTER, 1857). Lectotype, British Museum (Natural History) 57.6.4.2108/1, Mazatlán, Sinaloa, Mexico, $\times 35$ (ventral view). Photograph courtesy of and © by British Museum (Natural History)
 Figure 20: *Cypraeolina margaritula* (CARPENTER, 1857). Lectotype, British Museum (Natural History) 57.6.4.2109/1, Mazatlán, Sinaloa, Mexico, $\times 16.8$ (ventral view). Photograph courtesy of and © by British Museum (Natural History)



Figure 1

Figure 2

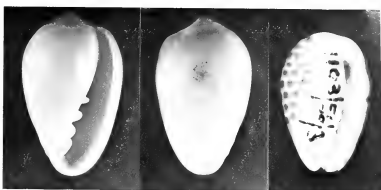


Figure 3

Figure 4

Figure 5



Figure 6

Figure 7

Figure 8

Figure 9

Figure 10



Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

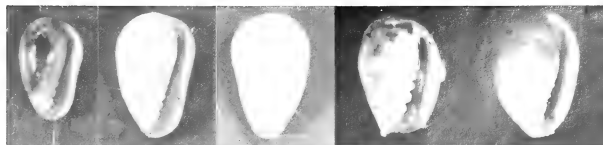


Figure 16

Figure 17

Figure 18

Figure 19

Figure 20



revisers" in the sense of Article 24a of the International Code of Zoological Nomenclature. The holotype of *Hyalina myrmecoon* is simply an elongate specimen of *Cystiscus politulus*.

Additional range records include the southern Gulf of California (Map). The Los Angeles County Museum of Natural History collection includes specimens recently collected by Dr. James H. McLean at Cabo San Lucas, Pulmo Reef, and Isla Cerralvo, Baja California Sur. We have tentatively determined as *Cystiscus politulus* a poor specimen from Bahía de las Banderas, mainland Mexico, so collectors should keep watch for the species in that area as well.

A specimen from Bahía Magdalena on the outer coast of Baja California Sur is here illustrated and discussed in connection with the description of a new species.

8. *Cystiscus jewettii* (CARPENTER, 1857a)

(Plate 7, Figures 15, 16; Text figure 1; Map)

COAN & ROTH, 1966: 291; pl. 51, figs. 66-68

From its previously reported distribution (Monterey, California, to Isla San Martin and Isla Guadalupe, Baja California) we can now extend the known range southward to Punta Abrejos, Baja California Sur. Note that this is still considerably north of the range of the next species. We are illustrating a specimen from Punta Abrejos and one from the northern end of the range, Point Pinos, Monterey County, California, for comparison with the new species described below.

Cystiscus jewettii is common in the intertidal area at Pacific Grove, Monterey County, California, where specimens were collected and observed in August, 1967 (Text figure 1). Throughout the period of observation, the

mantle was never extruded over the top of the shell of *C. jewettii* in the manner of *Cypraeolina margaritula* in the same dish.

9. *Cystiscus palantirulus* ROTH & COAN, spec. nov.

(Plate 7, Figures 17, 18 [Holotype]; Map)

Cystiscus sp., COAN & ROTH, 1966: 291-292; pl. 51, figs. 69-70

We have now seen a sufficient number of specimens of this form to propose a name for it.

Description of Holotype: Shell pear-shaped, broad and evenly rounded posteriorly, elongate and narrow anteriorly; white, smooth, highly polished; spire very low, covered by irregular callousing; outer lip extending high on body whorl, forming a 90° arc slightly anterior to the spire, most strongly thickened by callus posteriorly; apertural margin (columellar area) forming a long S-curve, concave anteriorly, very bulbous posteriorly, scarcely thickened by callus, with 2 large folds at base of columella and 4 smaller ones posterior to them, evenly decreasing in size, extending very slightly onto face of body whorl; aperture moderately wide anteriorly; anterior margin of aperture rounded; anterior end slightly flaring and twisted toward columella.

Dimensions of Holotype: Length 3.5 mm; width 2.1 mm.

Dimensions of Paratypes:

1. Length 3.1 mm; width 1.7 mm

2. Length 3.2 mm; width 1.7 mm

Paratypes: The two paratypes differ from the holotype in the following details: the apex of Paratype 1 projects as a minute nubbin; the apex of Paratype 2 is worn to a smooth dome; in curving to meet the spire, the outer lip of Paratype 1 changes direction by less than 90°.

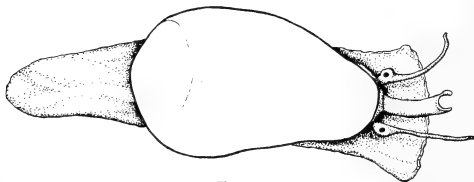


Figure 1

Cystiscus jewettii (CARPENTER, 1857)

Living specimen, Pacific Grove, Monterey County, California.

Intertidal $\times 14$

Type Locality: Station 89 of the *Puritan*-American Museum of Natural History Expedition to West Mexico: Los Frailes Bay, Baja California Sur (Gulf of California), 23°21' N by 109°25' W, 20-40 fathoms, fine sand, 19 April 1957, taken with the *Puritan* dredge.

Deposition of Types: Mollusk collection, American Museum of Natural History, New York, No. 128732 (Holotype) and AMNH No. 77942 (Paratypes).

Range: Specimens of *Cystiscus palantirulus* in other museum and private collections indicate a range limited to the southwestern part of the Gulf of California, from off Isla Monserrate to Cabo San Lucas, Baja California Sur (see Map), with one possible specimen from Acapulco, Guerrero. Collection records range from 6 to 80 m depth, plus 2 shore-collected dead shells. In addition to the type lot, we have examined the following material:

Los Angeles County Museum of Natural History:

Invert. Zool. Loc. 66-12, Cabo San Lucas, diving in 6-24 m near the pinnacle - 3 specimens

Invert. Zool. Loc. 66-17, dredged in 18 m between El Tule and Punta Palmilla, Baja California Sur - 35 specimens

Invert. Zool. Loc. 66-23, Between Punta Ventana and Isla Cerralvo, Gulf of California, 18-27 m - 12 specimens

California Academy of Sciences:

No. 24062, Bahía San Lucas - 2 specimens

San Diego Museum of Natural History:

No. 33654, Isla Espíritu Santo, Gulf of California - 1 specimen, juvenile

Locality L-2155, Isla Espíritu Santo - 3 specimens

Stanford University Paleontological Type Collection:

No. 9849, 10 miles north of Isla Espíritu Santo - one specimen (figured by COAN & ROTH, 1966)

Collection of Dr. Donald R. Shasky, Redlands, California: 37-73 m off Isla Monserrate, Gulf of California

Collection of Dr. S. Stillman Berry, Redlands, California: No. 10074, Acapulco, Guerrero - one specimen cf. *C. palantirulus*, but not recently re-examined

Discussion and Comparisons: A comparison of *Cystiscus palantirulus* with the other 2 west American species of *Cystiscus* is presented in Table 1.

Neither *Cystiscus jewettii* nor *C. palantirulus* has yet been taken in the area between Punta Abrejos and Cabo San Lucas (see Map). This apparent gap of about 400 coastal miles between the ranges supports the notion of *C. palantirulus* as a specifically distinct population. In addition, although *C. jewettii* exhibits consistent differences in form between the northern and the southern ends of its range (Plate 7, Figures 15, 16; and Table 1), and, although there is some individual variation between specimens from a single locality, there is no tendency for its populations to take on the distinctive shape of *C. palantirulus*.

In areas where their ranges overlap, *Cystiscus politulus* (Plate 7, Figures 13, 14) can be distinguished from *C. jewettii* or *C. palantirulus* by its narrower, more elongate aspect, and by its generally smaller size.

Etymology: The *palantiri*, from which the specific name is derived, are magical globes of crystal mentioned in the fiction of J. R. R. Tolkien.

Table 1

	<i>Cystiscus politulus</i>	<i>Cystiscus jewettii</i>	<i>Cystiscus palantirulus</i>
Size:	Small for genus; 2.9 mm (average of 10 from 6 localities)	Medium to large for genus; 4.8 mm (average of 2 northern specimens) 3.1 mm (average of 4 from Pta. Abrejos)	Medium for genus 3.2 mm (average of 27 from 9 localities)
Shape:	Elongate; not shouldered; length to width ratio 1.8 (average of 10 from 6 localities)	Ovate; shouldered; length/width ratio 1.5 (average of 6 from 3 local.)	Pear-shaped; shouldered; length/width ratio 1.6 (average of 27 from 9 localities)
Texture:		All species shiny, translucent	
Callousing:	Thin	Often thick, esp. on northern specimen	Thin
Spire:	Low to slightly elevated; not callus-covered	Low to well elevated (in south. spec.); northern specimens callus-covered	Low; sometimes mamillate
Outer Lip:	Slightly thickened at maturity	Much thickened at maturity	Slightly thickened
Aperture:	Anterior end rounded, even	Anterior end effuse, even	Anterior end effuse, twisted to left in dorsal view
Columella:	Much the same in all 3 species; also variable from specimen to specimen		
Range: (see Map)	Santa Barbara, California, to southern Gulf of California; intertidal to 60 m	Monterey, California, to Pta. Abrejos, Baja California Sur; intertidal to 50 m	Isla Monserrate to Cabo San Lucas, Baja California Sur; 6 to 80 m

10. *Kogomea polita* (CARPENTER, 1857b)

(Plate 7, Figure 19)

COAN & ROTH, 1966: 293; pl. 51, fig. 75; text fig. 3

We are illustrating the previously designated lectotype of this species by a photograph for the first time.

11. *Cypraeolina margaritula* (CARPENTER, 1857b)

(Plate 7, Figure 20; Text figure 2)

COAN & ROTH, 1966: 294-295; pl. 51, fig. 77; text figs. 4, 5

A photograph of the lectotype is provided.

One of a number of specimens collected in August, 1967, at Pacific Grove, Monterey County, California, where the species is abundant intertidally, is illustrated (Text figure 2). Its mantle is black, with red patches and minute spots of pale blue, and a narrow white margin. The rest of the animal was translucent tan, closely spotted with pale lemon-yellow.

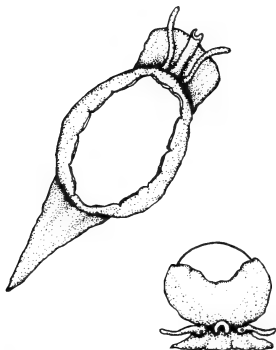


Figure 2

Cypraeolina margaritula (CARPENTER, 1857)

Living specimen, Pacific Grove, Monterey County, California.
Intertidal $\times 14$

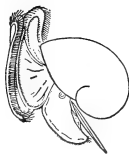
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On an Octopod from Placentia Bay, Newfoundland

BY

FREDERICK A. ALDRICH

AND

C. C. LU

Marine Sciences Research Laboratory
Memorial University of Newfoundland, St. John's, Newfoundland

(Plate 8)

IN CONTRAST TO THE ABUNDANCE of squid, octopods appear to be rare in Newfoundland waters. On October 28, 1967, a local fisherman obtained an octopod from water 60 fathoms deep, one mile west from Grass Island, Placentia Bay. Due to the rarity of octopods in this area, he brought the specimen to the Marine Sciences Research Laboratory on October 30, where it was turned over to the authors for study. Due to lack of proper treatment, the specimen was damaged and its surface somewhat peeled.

The animal is identified as *Benthoctopus piscatorum* (VERRILL, 1879) (Plate 8, Figure 1). The body is globular; its surface smooth and purplish brown in color. Arms are long and slender, tapering to the tips, and suckers are small. The measurements and indices are given in Table 1.

Benthoctopus piscatorum was first described by VERRILL in 1879 as *Octopus piscatorum*. The present genus was established by GRIMPE in 1921, with *B. piscatorum* as the type species. Specimens from fairly wide distributions, both vertical and horizontal, have been reported, i. e., Le Have Bank, Nova Scotia in 120 fathoms; Grand Bank in 200 fathoms; 39° 26' N, 70° 02' W, in 1362 fathoms (VERRILL, 1880 - 1881); 78° 02' N, 9° 25' E, in 416 fathoms (APPELLÖF, 1893); 66° 41' N, 6° 59' E, in 350

fathoms (APPELLÖF, 1893); 60° 40' N, 4° 50' W, in 563 fathoms (RUSSELL, 1909); 61° 27' N, 1° 47' W, in 681 fathoms (British Museum [quoted from ROBSON, 1932]); 51° 15' N, 11° 47' W, in 707 - 710 fathoms (MASSY, 1907); Farøe Channel in 540 - 608 fathoms (HOYLE, 1886). MUUS (1962) postulated that this species "might be expected" in the waters of Davis Strait west of Greenland. It is the first time that this species has been reported from the inshore waters of Newfoundland.

The specimen is a female, with a very large ovary, measuring 35 by 42 mm (Plate 8, Figure 2). The ovarian egg measures 18 by 6 mm. The spermathecae are globular, black and large, measuring 18 by 10 mm. The values quoted in Table 1 are considerably different from those presented by ROBSON (1932) for *Benthoctopus piscatorum*. The discrepancies are undoubtedly due to the preservation of our specimen.

The rarity of the octopod in Newfoundland waters may only be apparent and further collection by use of proper gear would increase our knowledge of the local octopodan fauna.

We wish to express our appreciation to Dr. G. L. Voss of the Institute of Marine Sciences of the University of Miami for sending us specimens from his collections for purpose of comparison.

Explanation of Plate 8

Figure 1: *Benthoctopus piscatorum* (VERRILL, 1879), dorsal view of specimen from Placentia Bay, Newfoundland.

Figure 2: Eggs (in situ) of described specimen of *Benthoctopus piscatorum* (VERRILL, 1879).



Figure 1

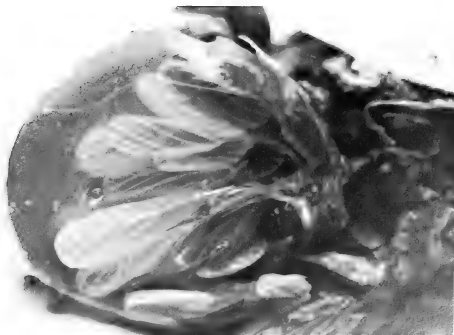


Figure 2

Table 1

Body proportions and indices of the examined specimen
of *Benthoctopus piscatorum* (VERRILL, 1879)
(following Voss, 1956 and 1963).

Body Proportions (length in mm)		
TL		362
ML		89
VML		58
MW		45
HW		31
SL		25
SW		12
A _I		260
A _{II}		203
A _{III}		212
A _{IV}		179
Web Depth:		
A		56
B		52
C		62
D		45
E		26
Number of gills: Left 10, Right 8		
Indices (%)		
MWI		50.68
HWI		34.57
MAL		34.15
WDI		23.85
ALI		71.82
SI _h		5.4
SLI		28.15
SWI		12.84

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A New Species of Enoploteuthid Squid, *Abraliopsis (Watasenia) felis*, from the California Current

BY

JOHN A. MCGOWAN

Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92037

AND

TAKASHI OKUTANI

Tokai Regional Fisheries Research Laboratory, Tokyo

(Plates 9 and 10; 1 Map)

INTRODUCTION

IN AN EXAMINATION of the extensive collection of pelagic cephalopods at the Scripps Institution of Oceanography a number of specimens of apparently undescribed species was found. One group of these specimens was so numerous and the series so complete that we have decided to describe it separately from the rest of the collection. A further reason for describing this species now is that it was discovered in a study of the distribution and abundance of the larval squid of the California Current that this species ranked first in abundance (OKUTANI & MCGOWAN, in press). Including larvae, juveniles and adults, we have examined about 1850 individuals of this new species.

ACKNOWLEDGMENTS

The specimens reported on here were collected by many individuals of the staff of the Scripps Institution of Oceanography. Twenty specimens were obtained from Dr. William Percy of Oregon State University. Mr. Charles B. Miller made many of the measurements and Mr. Kenneth H. Isaacs sorted many of the specimens. This work was supported by the Marine Life Research Program, the Scripps Institution of Oceanography's part of the California Cooperative Oceanic Fisheries Investigations, which are sponsored by the Marine Research Committee of the State of California and by the National Science Foundation Grant GB 2861.

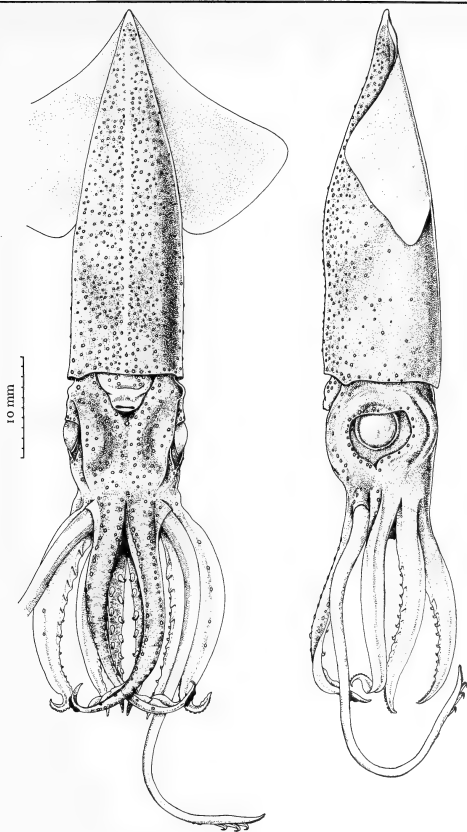
Abraliopsis (Watasenia) felis MCGOWAN & OKUTANI,
spec. nov.

(Plates 9 and 10)

Synonyms: None.

Diagnosis: An *Abraliopsis* with a double row of tentacular hooks, the ventral row of which consists of 3 or occasionally 4 large hooks and the dorsal row of 3 or occasionally 4 small hooks. The fixing apparatus on the carpus is compact and consists of 4 suckers and 7 knobs. The right ventral arm and occasionally both the right and left ventral arm of the male is hectocotylized. The hectocotylus consists of two semilunar membranes on the lateral edges of the arm just proximal to the 3 large photophores of the arm tip. These membranes are offset from one another, the inner one being more proximal than the outer. The ventral surface of the mantle with many small photophores arranged randomly but with a narrow median bare area running the entire length of the mantle. The body is elongate and fusiform with the width being less than $\frac{1}{3}$, but more than $\frac{1}{4}$ the length.

Description: The body is muscular and firm. The mantle shape is fusiform and somewhat elongated. Based on measurements of 94 adult specimens, the width is less than $\frac{1}{3}$ of the dorsal mantle length but more than $\frac{1}{4}$ of the dorsal mantle length. The broadest part of the mantle is at the free margin which flares out slightly. The dorsal margin of the mantle is triangularly lobed and projects slightly at the mid-point. On the ventral side there are



Abraliopsis (Watasenia) felis McGOWAN & OKUTANI, n. sp.

Holotype, Male

slight angular projections at the position of both funnel cartilages. Between these two projections the margin is slightly concave (Plate 9).

The fins are broadly sagittate with the posterior margin being slightly concave and the anterior margin somewhat convex. The width of both fins, taken together, is about 86% of the mantle length (22 adult specimens measured, see Table 1). The free margins of the fins are thinner than the remaining parts.

The head is rather large and is as wide as the mantle and approximately $\frac{1}{3}$ as long as the mantle length. The eye opening has a distinct sinus on the anterior edge at about the position of the third arm. There are 3 nuchal folds on either side of the head, the ventral 2 of which are semi-lunar in shape and the dorsal one somewhat squared and elongated (Plate 10, Figure 1). The central fold bears an "olfactory organ."

The neck is constricted and distinct and has a shallow funnel excavation. The funnel is conical and short. The funnel organs consist of a dorsal V-shaped pad and two ventral oblong pads (Plate 10, Figure 3). There is a transverse fold anterior to the dorsal funnel organ. The funnel cartilages are about 3 times as long as wide and

have a slightly curved but simple groove (Plate 10, Figure 1). The nuchal cartilage is straight, spatulate and bilaterally symmetrical. It is widened a little on both ends.

The arms are nearly equal in length with an arm formula 4, 3, 2, 1 or 4, 2, 3, 1. The dorsal arms have a low membranous keel on the distal $\frac{1}{3}$. The oral face of the dorsal arms has from 12 to 17 hooks arranged in a zigzag row (Table 1, based on 12 specimens). Distal to the hooks are 10 to 18 suckers, also alternating in a zigzag row. The outer margin of the hook-bearing face of these arms has a low swimming membrane supported by numerous muscular filaments. The second arms are similar to the dorsals except that they tend to have a slightly greater number of hooks. The third arms have well-developed aboral keels extending along the entire length of each arm. The armature is similar to that of the second but with fewer distal suckers and somewhat fewer hooks (Plate 10, Figure 7). The ventral arms have aboral keels their entire length. They have from 7 to 14 hooks in a zigzag row but no distal suckers. Generally the right ventral arm is hectocotylized but in an examination of 39 males, 2 of them had both the right and the left ventral arms hectocotylized. The hectocotylus is a pair of semi-

Table 1
Measurements of Types

		Holotype	Paratype 1 (= Allotype)	Paratype 2	Paratype 3
Total length (including tentacle)		84.8	105.5	—	80.0
	mm				
Mantle length, mm		36.7	41.7	33.5	39.2
Mantle width, mm		10.6	12.4	10.2	11.8
Fin length at attachment, mm		20.5	25.0	16.0	21.6
Width across the fins, mm		26.2	33.8	26.1	29.8
Width of the head (inter-ocular length), mm		10.6	11.1	11.5	9.5
Head length (from anterior end of nuchal cartilage to the proximal end of the dorsal arms), mm		12.7	11.0	10.1	12.0
Eye (transverse length \times longitudinal length of eye opening), mm		5.5 \times 5.5	5.9 \times 4.5	4.1 \times 3.3	4.3 \times 3.5
Dorsal arm:					
length, mm	Right	18.9	17.8	12.5	18.0
	Left	18.1	18.5	13.0	16.0
Second arm:					
length, mm	Right	20.9	21.8	15.8	21.0
	Left	20.2	21.8	14.2	20.2
Third arm:					
length, mm	Right	19.2	22.8	16.6	—
	Left	19.3	22.4	15.0	—
Ventral arm:					
length, mm	Right	21.5	27.0	—	24.0
	Left	21.8	27.0	—	21.0
Tentacle:					
length, mm	Right	37.0	42.7	—	34.1
	Left	32.2	41.0	—	—

lunar membranes offset from one another with the inner membrane being somewhat more distal than the outer (Plate 10, Figures 6, 6a, 6b). Between these crests is a deep groove.

The tentacle is as long as the mantle and has a gradually tapered stem which is flattened on the oral surface. The club (or manus) is not expanded and occupies $\frac{1}{2}$ to $\frac{1}{3}$ of the tentacle length. There is no membrane on the outer side of the club. The armature of the proximal portion of the club consists primarily of hooks arranged in two rows. In the ventral row there are 3 or occasionally 4 large hooks and muscular pads are sometimes present between these. The dorsal row consists of 3 and occasionally 4 small hooks which are usually about half the size of the large hooks (Plate 10, Figures 5a and 5b). There are very small suckers and sometimes pads between these hooks. The distal part of the club has 13 transverse rows of 4 suckers each. The horny rings of these suckers have 5 to 6 rather blunt teeth on the margin (Plate 10, Figure 5a). The carpus bears a fixing apparatus which consists of 4 suckers arranged in a quadrate and 6 to 7 small papillae or knobs (Plate 10, Figure 5).

The mantle has many photophores, particularly on its ventral surface. These range in size from 150μ to 250μ . There is an almost random arrangement of these, but a narrow longitudinal strip without photophores exists on the mid-ventrum. The funnel has about 60 photophores, particularly on the ventral side, but also on the dorsum. The ventral surface of the head also has photophores on its integument, but these are arranged in no consistent order except about 28 surrounding the periphery of the eyes (Plate 9). The eyeball has 2 large (600μ) and 3 small (400μ) photophores along the ventral periphery. The third arms have a row of 9 to 11 photophores on the ventral surface. The ventral arms bear 3 rows of photophores of which the dorsal-most consists of 5 small ones on the keel. The other 2 rows are along both edges of the aboral surface (Plate 9). Very near the distal tip of the ventral arms are 3 very large ellipsoid luminous organs about 0.8 mm in length (Plate

10, Figure 6). Distal to these are 4 small photophores. These large luminous organs are a characteristic feature of the genus.

The buccal membrane has 8 supporting muscles and its inner surface is heavily papillated (Plate 10, Figure 2).

The radula is quite delicate and has 7 unicuspid rhabdodont teeth in a row and no accessory plates (Plate 10, Figure 4). The gladius is penniform with a maximum width about $\frac{1}{2}$ of the length. The rhachis has a sharp keel which appears as a dark streak on the dorsum of the mantle. The spermatophores are about 5.5 mm in length and 0.16 mm wide. The sperm cord is thick and occupies about $\frac{2}{3}$ of the length. The distal portion of this is opaque and without structure, posterior to this it coils $2\frac{1}{2}$ to 3 times and continues to a striated portion (Plate 10, Figure 8).

Types:

Holotype (male): Station 87.90 of CalCOFI Cruise 25 ($31^{\circ}59'N$, $122^{\circ}24'W$), May 1951.

Paratype No. 1 (female): ($32^{\circ}39.3'N$, $117^{\circ}37.2'W$), August, 1953.

Paratype No. 2 (male): ($32^{\circ}49'N$, $117^{\circ}43'W$), August 1953.

Paratype No. 3 (male): St. 93.90 of CalCOFI Cruise 5704 ($30^{\circ}49.5'N$, $121^{\circ}32'W$), April 1957.

Deposition of Types:

Holotype: U. S. National Museum, one male, USNM 678792

Paratype 1: U. S. National Museum, one female, USNM 678793

Paratype 2: California Acad. Sci. Dept. Invert. Zool., one male, CAL Acad. Invert. Type Coll. No. 310

Paratype 3: Scripps Institution of Oceanography, Marine Invertebrate Collections, one male.

DISCUSSION

There are at least 3 other species of the genus in the North Pacific. As is frequently the case with oceanic invertebrates, which are difficult to collect, many of the

Explanation of Plate 10

Abrialopsis (Watasenia) felis McGOWAN & OKUTANI, n. sp.

Figure 1: Latero-ventral view of the cephalic part (Paratype No. 3, male) showing funnel cartilage, olfactory lobe, nuchal folds and the funnel adductors. The photophores on the eyeball are shown by removing a part of the eye lid. The photophores on the integument are not drawn.

Figure 2: Buccal membrane (Paratype No. 3). Vento-anterior view. Figure 3: Funnel organ (Paratype No. 3). The funnel is cut open.

Figure 4: Three transverse rows of the radula (Paratype No. 3).

Figure 5: Club and carpus of the tentacle (Holotype).

Figure 5a: A large sucker of the tentacle (Paratype No. 3).

Figure 5b: A large hook of the tentacle (Paratype No. 3).

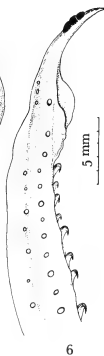
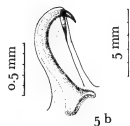
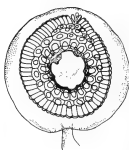
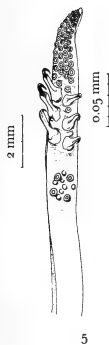
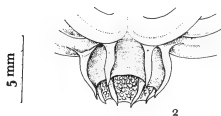
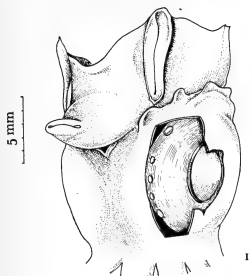
Figure 6: Right ventral arm of the male (Paratype No. 2).

Figure 6a: The distal tip of the right hectocotylized arm (Holotype).

Figure 6b: The distal tip of the left hectocotylized arm (Holotype).

Figure 7: Left third lateral arm (Holotype).

Figure 8: A spermatophore taken from the spermatophore sac (Paratype No. 3).



descriptions and reports of these species are confusing and contradictory because they are based on immature or damaged specimens. Further, the problem of discriminating between these species is difficult because the authors did not report the ranges over which important meristic, taxonomic characters varied. It has been necessary, therefore, to re-examine these and other characters of two closely "related" species, *Abraliopsis (Watasenia) scintillans* BERRY, 1911 and *Abraliopsis affinis* (PFEFFER, 1912). The former is closely related to our new species in a morphological sense and the latter has a contiguous and occasionally overlapping geographical distribution.

Abraliopsis scintillans from Japanese waters was described by BERRY in 1911 and 1912. However, earlier WATASE (1905) had reported a new species of the genus from Japan but did not describe it. ISHIKAWA (1913) in reviewing the characteristics of this species decided that Berry's and Watase's squids were identical and created the new genus *Watasenia* (= *Watasia* ISHIKAWA, 1913) for it. This was done on the basis that Berry's *A. scintillans* had only 2 large tentacular hooks instead of the 3 large and 3 small ones of *A. morisii* (VERANY, 1837) or 5 large and 5 small ones of *A. pfefferi* JOUBIN, 1896. A further distinction of the new genus was based on the fact that the right ventral arm was hectocotylized with 2 small semi-lunar membranes near the tip. This, according to ISHIKAWA, set it off from *A. morisii* and presumably other members of the genus because CHUN (1910) after synonymizing most other species of the genus with *A. morisii* illustrates a spectacularly enlarged swimming web (or "Schutzsaum") on the left ventral arm which he calls the hectocotylus (plt. 6, fig. 1 and plt. 10, fig. 1). However, in at least one of the species he synonymized (namely *A. hoylei* of HOYLE, 1904, which PFEFFER, 1912 described as a new species, *A. affinis*, see below) this large swimming web is not the hectocotylus. The hectocotylus of *A. hoylei* (of HOYLE, 1904, not of PFEFFER, 1884 or 1912 but rather = *A. affinis* PFEFFER, 1912) is on the right ventral arm and is somewhat similar to those of *A. scintillans* BERRY, 1911 and *A. felis*, spec. nov. Further, Voss (1960) mentions having a specimen of *A. morisii* with the right ventral arm hectocotylized. The type of hectocotylization is not mentioned. Therefore one of the two characters ISHIKAWA uses to distinguish his new genus *Watasenia* is common in the genus *Abraliopsis* and cannot be used to set off *Watasenia* uniquely. The other character used by him, the presence of only 2 hooks on the tentacle club rather than the 6 to 10 found in the other members of the genus seems to us to be insufficient for the creation of a new genus. At best, *Watasenia* can be considered only a subgenus of *Abraliopsis* JOUBIN, 1896. We so consider it here.

The differences between *Abraliopsis scintillans* and *A. felis* are listed in Table 1. It is evident that *A. felis* has a different body shape and mantle length to fin width ratio. It has more hooks on the manus of the tentacles and the fixing apparatus of the tentacle carpus differs. The ventral mantle photophores are arranged somewhat differently and the arms have, generally, more hooks but fewer distal suckers than in *A. scintillans*. Most of the differences between these species are quantitative rather than qualitative; however, they are consistent and significant and may be used for a rather easy visual separation of specimens. It is obvious that the two species are closely related and should be considered members of the subgenus *Watasenia*.

South of the area occupied by *Abraliopsis felis* a second species of the genus, *A. affinis* (PFEFFER, 1912), is found in abundance (see Map). The first report of the presence of this species in the eastern tropical Pacific was that of HOYLE in 1904 who illustrated it and identified it as *Abraliopsis hoylei* JOUBIN, 1896 (= *Enoplateuthis hoylei* PFEFFER, 1884). However, PFEFFER (1912), without apparently seeing any specimens and using HOYLE's description and figures as a basis, claimed that HOYLE's specimens were not the *A. hoylei* that he had described in 1884, but rather a new species, *Abralia* (= *Abraliopsis*) *affinis*, which he proceeded to describe. PFEFFER further re-described his *A. hoylei* in more detail and it is clear that HOYLE's specimens do not fit this description. In spite of this, ROBSON (1948) reports that 8 specimens (one male) were collected in the vicinity of the Galapagos and Cocos Islands by the Arcturus Expedition. ROBSON chose to call these specimens *A. hoylei* PFEFFER. But he did not illustrate the specimens, gave no counts of meristic characters and apparently has confused the swimming web of the left ventral arm with the hectocotylus. Further, his single male specimen was "damaged" and "not very well preserved" (*op. cit.*, p. 118). It would seem, therefore, that *Abraliopsis affinis* (PFEFFER, 1912) must be considered a valid species.

We have in our collection at Scripps Institution of Oceanography several hundred specimens of an *Abraliopsis* species from the eastern tropical Pacific that fit both HOYLE's (1904) illustrations of "*A. hoylei*" and PFEFFER's (1912) description of *A. affinis* very well. There is no doubt that they are the *A. affinis* of PFEFFER, 1912, but because his original descriptions are incomplete, additional details need to be added. For example, the left ventral arm is as HOYLE shows it and resembles strongly the left ventral arm of *A. morisii* as figured by CHUN (1910); that is, with a greatly enlarged swimming web. CHUN called this swimming web "the hectocotylus." While this is a good secondary sexual characteristic, being

Table 2
A Comparison of Several Species

Character	<i>Abrotipis felix</i> , n. sp.	<i>Abrotipis scintillans</i> Beary	<i>Abrotipis affinis</i> (Petersen, 1912) *	<i>Abrotipis hoykei</i> (Petersen, 1884) *
Tentacle structure	3, or occasionally 4 large hooks and 3 or occasionally 4 small hooks in a double row. No membrane on club.	2 large hooks and no small hooks. Club with semilunar membrane on outer side.	3 large and 4 small hooks in a double row. Club with semilunar membrane on outer side.	4 large and 4 small hooks in a double row.
Fixing apparatus	4 suckers and 7 knobs, compact.	3 or 4 suckers and 3 knobs, somewhat diffuse.	3 to 5 suckers and knobs, compact.	4 or 5 suckers and 7 knobs.
Heterocystus	Right or occasionally left and right ventral arms. Two small semilunar crests, offset.	Right ventral arm. Two small semilunar crests, offset.	Right ventral arm with 3 small semilunar crests, offset. Left ventral arm with greatly enlarged swimming web 3 X width of arm.	Not described.
Ventral mantle photophores	A "random" arrangement but with a narrow median bare area entire length of mantle.	An almost even arrangement with median bare area entire length of mantle.	Arranged in longitudinal rows with wide median bare area terminating on distal $\frac{1}{2}$ of mantle in bare circular patch.	Somewhat irregularly arranged but tend to be in longitudinal rows. Narrow median bare area on posterior $\frac{1}{2}$ of mantle.
Arms, hooks	1 st L. range = 15-17, \bar{x} 16 1 st R. range = 12-17, \bar{x} 15.4 2 nd L. range = 16-18, \bar{x} 17 2 nd R. range = 16-19, \bar{x} 17.4 3 rd L. range = 15-16, \bar{x} 15.9 3 rd R. range = 13-17, \bar{x} 16 4 th L. range = 10-14, \bar{x} 11.8 4 th R. range = 7-14, \bar{x} 11.4 1 st L. range = 13-18, \bar{x} 15 1 st R. range = 10-18, \bar{x} 13 2 nd L. range = 13-18, \bar{x} 15 2 nd R. range = 12-20, \bar{x} 16 3 rd L. range = 4-18, \bar{x} 12.3 3 rd R. range = 6-18, \bar{x} 12.1	1 st L. range = 9-12, \bar{x} 10.8 1 st R. range = 8-12, \bar{x} 10.5 2 nd L. range = 11-14, \bar{x} 13.1 2 nd R. range = 11-14, \bar{x} 12.7 3 rd L. range = 10-14, \bar{x} 12.2 3 rd R. range = 12-15, \bar{x} 12.5 4 th L. range = 9-11, \bar{x} 10.2 4 th R. range = 9-12, \bar{x} 10.4 1 st L. range = 56-34, \bar{x} 29 1 st R. range = 27-31, \bar{x} 28 2 nd L. range = 28-34, \bar{x} 31 2 nd R. range = 24-34, \bar{x} 28.6 3 rd L. range = 28-34, \bar{x} 29.5	1 st L. range = 14-25, \bar{x} 18.2 1 st R. range = 15-27, \bar{x} 19 2 nd L. range = 16-26, \bar{x} 20.6 2 nd R. range = 16-26, \bar{x} 20.4 3 rd L. range = 16-24, \bar{x} 19.8 3 rd R. range = 13-24, \bar{x} 19.7 4 th L. range = 14-47, \bar{x} 31 4 th R. range = 17-40, \bar{x} 24 1 st L. range = 10-24, \bar{x} 16 1 st R. range = 8-22, \bar{x} 15 2 nd L. range = 6-26, \bar{x} 11 2 nd R. range = 3-20, \bar{x} 11 3 rd L. range = 6-14, \bar{x} 9.8 3 rd R. range = 7-14, \bar{x} 10.8	1 st L. range = 14-25, \bar{x} 18.2 1 st R. range = 15-27, \bar{x} 19 2 nd L. range = 16-26, \bar{x} 20.6 2 nd R. range = 16-26, \bar{x} 20.4 3 rd L. range = 16-24, \bar{x} 19.8 3 rd R. range = 13-24, \bar{x} 19.7 4 th L. range = 14-47, \bar{x} 31 4 th R. range = 17-40, \bar{x} 24 1 st L. range = 10-24, \bar{x} 16 1 st R. range = 8-22, \bar{x} 15 2 nd L. range = 6-26, \bar{x} 11 2 nd R. range = 3-20, \bar{x} 11 3 rd L. range = 6-14, \bar{x} 9.8 3 rd R. range = 7-14, \bar{x} 10.8
Body shape	Elongate, fusiform	Elongate, fusiform	Short, semifusiform	"Short semifusiform"
	Width $\leq \frac{1}{4}$ length	Width $\leq \frac{1}{4}$ length	Width $\leq \frac{1}{4}$ length	Width $\leq \frac{1}{4}$ length
Mantle length (mm)	Range = 1.0-1.3	Range = 1.2-1.4	Range = 0.96-1.1	0.91, single specimen
Fin width (mm)	\bar{x} = 1.11	\bar{x} = 1.28	\bar{x} = 0.98	
Mantle length (mm)	Range = 0.74-3.66	Range = 0.57-0.86	Range = 0.90-2.8	
Volume cm ³	\bar{x} = 1.28	\bar{x} = 0.67	\bar{x} = 1.50	
Eye ball	2 large	2 large	2 large	1 large
Photophores	3 small	3 small	3 small	4 small
Geographic range	California	Current	Coastal waters of Japan, Korea and Okhotsk Sea	A single specimen, "presumably from the Mascarenes," Indian Ocean.

found only in the males, it is not the hectocotylus. The right ventral arm of this species is hectocotylized just as is the right ventral arm of *A. scintillans* and *A. felis*. This hectocotylization (in *A. affinis*) takes the form of 3 small semilunar membranes near the tip of the right ventral arm just posterior to the 3 large swellings that contain the light organs. These membranes are offset from one another, 2 of them are on the inner and 1 on the outer lateral edges of the oral surface of the arm. The most proximal of these is somewhat larger than the other 2. It may be seen in Table 1 that the number of hooks on this arm is fewer than on the left ventral arm. The females of *A. affinis* do not, of course, have a hectocotylus nor do they possess the greatly enlarged swimming web. The web of the left ventral arm of the female is similar to the male's but very much smaller, being only about $\frac{2}{3}$ as wide as the arm width. That the specimens examined were, as a matter of fact, females of *A. affinis* was determined by examining them for the presence of ovaries and by comparing the other taxonomic characters to those of the male. A particularly useful character for this purpose is the arrangement of the ventral mantle photophores.

These ventral mantle photophores were illustrated well by HOYLE (1904, pl. 10, fig. 1), but he did not discuss the uniqueness of their arrangement nor did PFEFFER in his description of *A. affinis*. In the more than 100 specimens examined by us, both the males and females of this species have rather indistinct longitudinal rows of photophores on their ventral mantle surface but with a very broad medial area lacking such photophores. This bare area begins at the anterior edge of the mantle and terminates on the distal $\frac{1}{3}$ of the mantle in a bare, circular patch somewhat greater in diameter than the width of the medial bare area.

A fourth species of this genus is present in our collections from the waters off southern Baja California. It resembles greatly CHUN's (1910) description and illustrations (particularly pl. X, fig. 1) of *Abrialopsis morisii* (VERANY, 1837). We cannot, however, formally identify it as such because the hectocotylus of our specimens is similar to that of *A. scintillans*, *A. affinis* and *A. felis*,

that is, small semilunar membranes near the tip of the right ventral arm. The left ventral arm of these Baja California specimens have the enlarged swimming web as illustrated by CHUN in *A. morisii* and which he called the hectocotylus. Until the Atlantic and Indian Ocean species of this genus (*A. morisii*, *A. pfefferi* and *A. hoylei*) are re-examined and the nature of the hectocotylization of the ventral arms clarified, no further discussion of this fourth North Pacific species seems warranted.

Natural History: The identifying characteristics, distribution and abundance of the larvae and juveniles of *Abrialopsis felis* spec. nov. have been studied (OKUTANI & MCGOWAN, in press). The larvae of this species were found to be the most abundant ones in the California Current. They are more than five times as numerous as the larvae of *Loligo opalescens* BERRY, 1911. Seasonal studies on the occurrence of the larvae show them to be both most abundant and most frequent during the months of June and July and although some larvae are found all year, this probably indicates that the peak spawning activity is in the early summer. They are more abundant offshore (i.e., greater than 50 nautical miles from the coast) than inshore and more abundant in the central sector of the California Current (i.e., between Point Conception [34°30'N], California and Punta Eugenia [27°51'N], Baja California, Mexico). Based on an examination of 91 adult specimens the male to female ratio

$$\frac{\text{male}}{\text{female}} = 0.75.$$

Thus far this species has been found only in the California Current (see Map).

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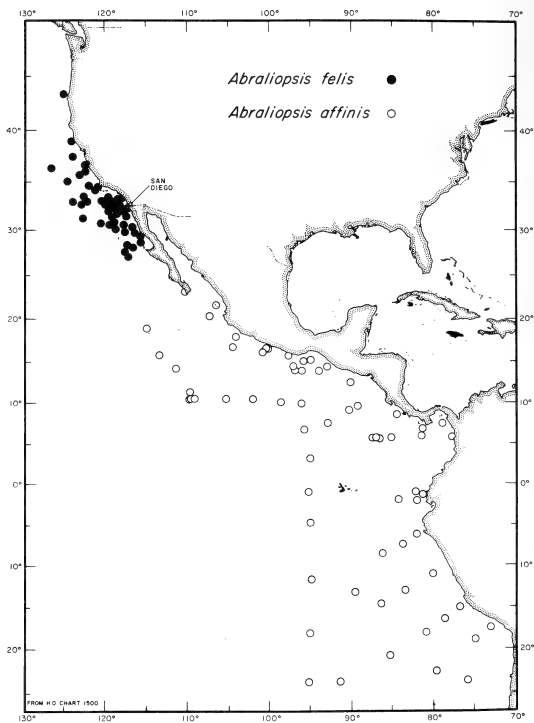
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← Explanation to Table 2

¹ This is based primarily on an examination of 136 specimens in our collections. The data presented here do not disagree with PFEFFER's description but merely enlarge upon it.

² Based entirely on PFEFFER, 1912.

³ It is obvious that the range over which this character varies overlaps that of *A. scintillans*; however, by the Mann-Whitney "U" test the differences between the means for the two species is significant, $p < 0.001$ (TATE & CLELLAND, 1959, p. 89).



Localities at which specimens of *Abraliopsis felis* and *A. affinis* have been collected. The solid circles indicate *A. felis*, the open circles *A. affinis*.

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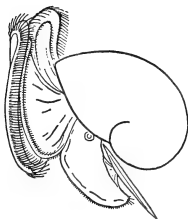
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NOTES & NEWS

*Tellina ulloana*A New Species from Magdalena Bay,
Baja California, Mexico

BY

LEO G. HERTLEIN

Tellina declivis SOWERBY, 1868 (species 261, pl. 44, fig. 261) was described without information as to the locality from which it came. *Tellina declivis* CONRAD, 1834 (p. 131) was described from the late Tertiary of Yorktown, Virginia. This made necessary a new name for *T. declivis* SOWERBY. DALL (1900, p. 301) on the basis of the original figure, judged the form to be a West American species, and in this he has been followed by other authors. We proposed a replacement name for the homonym as *Tellina (Merisica) proclivis* HERTLEIN & STRONG (1949, p. 83; pl. 1, figs. 6, 7, 14), with an illustration of a West American specimen.

Recently Dr. Kenneth J. Boss examined Sowerby's holotype and found that it is not a West American form. An illustration of that specimen shown to me recently by Eugene Coan bears out Boss' observation.

Under the International Code of Zoological Nomenclature (Art. 72d), the replacement name applies to Sowerby's species and not to the West American form that had been erroneously identified as *Tellina declivis*. Therefore, *Tellina ulloana* HERTLEIN is here proposed as a new species, based upon type specimen 9226 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from Magdalena Bay, Baja California, with the description, illustrations and other details as given by HERTLEIN & STRONG for *T. proclivis*. This species has been reported as ranging south to Panama.

Both Boss and Coan called my attention to the similarity between the West American species here described as *Tellina ulloana* and the Caribbean species *T. martinicensis* D'ORBIGNY, 1842 (see WARMKE & ABBOTT, 1961, p. 196; pl. 40, fig. i).

Dr. Boss informed me (written communication October 20, 1967) that the type specimen of *Tellina declivis* (*T. proclivis*) appears to be macomoid, perhaps from the Caribbean but possibly elsewhere. LYNCE (1909, p. 193) cited "*Tellina (Arcopagia?) declivis* SOWERBY" from the Gulf of Thailand (Gulf of Siam) and from Singapore

and stated, "My specimens exactly agree with SOWERBY's description and figure."

This species is named for Francisco de Ulloa, the first navigator to reach the head of the Gulf of California in September, 1539.

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AN EMENDATION

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles,
California 90049

It has come to my attention that a recent paper on West Australian cowries (CATE, 1968) contains some inaccuracies and errors which I wish to correct. They are as follows:

Entry 18, p. 227: *Cypraea (Lyncina) leviathan gedlingae* CATE, 1968. — The diagnosis of this new subspecies was omitted. The shell of *C. (L.) leviathan gedlingae* differs from that of *C. (L.) l. leviathan* SCHILDER & SCHILDER,

1937 by being narrower, more cylindrical, less pyriform; more thickly, more solidly formed; by apparently being a smaller form (it will require additional live collected material to determine this); and by apparently being geographically isolated from the presently known range of the nominate subspecies. Since publication of the above mentioned article another specimen of *C. (L.) l. gedlingae* has been received; it was collected by Molly Gedling in 1962 on the beach just S of Vlaming Head Light, North West Cape.

Entry 19, p. 227: The data should read as follows:

(26.5 12.3 10.0 30 25)

Entry 32, pp. 220 and 228; The designations for the species in the text and on plate 29, fig. 42 are incorrect. They should be corrected to read: *Erosaria (Erosaria) lamarckii lamarckii* (GRAY, 1825). For the reference on p. 220 read: Zool. Journ. 1: 506

Entry 37, p. 29: The data should read as follows:

(17.9 11.0 8.5 19 17)

Entry 61, p. 232: The assertion is made that the "species is clearly separable from *Bistolida s. stolidus* because of the total absence of lateral marks at each quarter of the shell." *Bistolida brevidentata* does possess lateral marks on the angle of the shell margins; however, what I intended to convey is that these markings do not normally become broader, extending up the sides of the shell, often coming into direct contact with the large central, chestnut-brown color blotch as in *B. s. stolidus*. This particular shell pattern is almost never seen in *B. brevidentata*.

The indications of magnification for figs. 26 (plate 26) and 33 (plate 27) should be corrected to $\times 1\frac{1}{2}$.

LITERATURE CITED

CATE, CRAWFORD NEILL

1968. West Australian cowries. — a second, revised, and expanded report. The Veliger 10 (3): 212-232; pls. 21-34; 5 maps. (1 January 1968)

CORRECTION OF AN OMISSION

The title of the paper by Dr. E. C. Haderlie, starting on page 327 of our April 1968 issue should read the same as in the Table of Contents, i. e.

Marine Fouling and Boring Organisms
in Monterey Harbor.

The two words "and Boring" were omitted quite accidentally; in citing the work these two words should, of course, be included. Your Editor apologizes for this very regrettable oversight on his part.



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Because of the changed rules affecting second class mail matter, we will no longer be able to include the customary reminders in our January issue, nor can we attach any flyers to our journal henceforth. We shall, from now on, print a statement when dues-renewal time has arrived or announcements regarding special publications in our NOTES & NEWS column.

Manuscripts received up to February 14 each year will be considered for publication in our July issue; May 14 is the deadline for the October issue, August 14 for the January issue and November 14 for the April issue. For very short papers of less than 500 words (including title, etc.) the deadlines are one month later than those given above, provided that these short notes are impor-

tant enough to warrant preferential treatment. It is, however, understood that submission of a manuscript before the dates indicated is not a guarantee of acceptance.

On May 15, 1968 we published the second part of the supplement to Volume 3 and mailed it to those of our members and subscribers who, according to our records, had purchased Part 1 before December 31, 1964.

Part 2 will be available at \$3.- plus a handling charge of \$-.35 (plus sales tax, for California residents).

The complete supplement is available at \$6.- plus a handling charge of \$-.45 (plus, again, the sales tax for California residents).

We deplore the long delay in the publication of Part 2 as it is our policy to publish as promptly as is technically feasible. But unusual and completely unpredictable circumstances over which we had absolutely not the slightest control are responsible. We also regret that the delay may have inconvenienced some of our readers who had given up hope of ever seeing Part 2 in print and therefore had their journal bound. To these readers we extend our apologies.

We are pleased to announce the publication on July 15, 1968 of a Supplement to Volume 11, entitled:

The Biology of Acmaea

edited by D. P. Abbott, D. Epel, I. A. Abbott and R. Stohler. This supplement is a group of 20 papers dealing with various aspects of the biology of several different species of limpets. It comprises 112 pages, 7 halftone plates and numerous text figures, charts and tables. This supplement, like all our supplements, will be sold on separate order only. The price is \$5.- plus a handling charge of \$0.35; however, members in good standing are granted a discount of 20% on the sales price provided remittance for the correct amount is received before June 30, 1969. No discount can be granted after that date. California residents must add the appropriate amount of sales tax.

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Affiliate Membership in the C. M. S., Inc. is \$6.- for the fiscal year July 1, 1967 to June 30, 1968. Postage for members living in Canada, Mexico, Central and South America 80 cents, for members living in any other foreign country \$1.20 additional. Membership open to individuals only - no institutional memberships. Please, send for membership application forms to the Manager or the Editor.

At a Regular Membership Meeting of the CALIFORNIA MALACOOLOGICAL SOCIETY, Inc. the following policies were adopted by unanimous vote:

There will be an initiation fee of \$2.- (in addition to the annual dues) for persons joining the Society on or after January 1, 1967.

Members receive The Veliger free of further charges and are entitled to purchase one copy of any supplement published during the current membership year at a special discount (to be determined for each supplement).

Membership renewals are due on or before April 15 each year. If renewal payments are made after April 15 but before March 15 of the following year, there will be a re-instatement fee of \$1.-. Members whose dues payments (including the re-instatement fee) have not been received by the latter date, will be dropped from the rolls of the Society. They may rejoin by paying a new initiation fee. The volume(s) published during the time a member was in arrears may be purchased, if still available, at the regular full volume price plus applicable handling charges.

CALIFORNIA

MALACOOLOGICAL SOCIETY, Inc.

is a non-profit educational corporation (Articles of Incorporation No. 463389 were filed January 6, 1964 in the office of the Secretary of State). The Society publishes a scientific quarterly, the VELIGER. Donations to the Society are used to pay a part of the production costs and thus to keep the subscription rate at a minimum. Donors may designate the Fund to which their contribution is to be credited: Operating Fund (available for current production); Savings Fund (available only for specified purposes, such as publication of especially long and significant papers); Endowment Fund (the income from which is available. The principal is irrevocably dedicated to scientific and educational purposes). Unassigned donations will be used according to greatest need.

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BOOKS, PERIODICALS, PAMPHLETS

Marine Botany: An Introduction

by E. YALE DAWSON. Holt, Rinehart and Winston, Inc. New York. 1966. pp. xii + 371; illust. \$10.95

The malacologist will find this a useful reference work if for no other reason than that it aids in the recognition of the seaweeds among which mollusks occur. It is more than an identification manual, however, for there are chapters on the marine environment, bacteria, fungi, phytoplankton, the several groups of algae, their morphology, physiology, ecology and distribution. The three final chapters are on the history of the study of seaweeds, utilization of marine algae, and collecting procedures. Two appendices bring together several lists of useful information, such as the research facilities of the United States where marine collections are housed.

We may be glad that Yale Dawson was able to see this book into print before his tragic drowning. It is a book that one can read without feeling bogged-down by special terminology, yet the technical terminology is there when needed. Numerous line drawings and halftone pictures are well chosen as illustrations.

MK

VENUS The Japanese Journal of Malacology

Vol. 25, nos. 3 and 4, July 1967. Some papers from the Eleventh Pacific Science Congress, Tokyo, 1966

Indo-Pacific faunal elements in the Tropical Eastern Pacific, with special reference to the mollusks. -

WILLIAM K. EMERSON

The composition and relationships of marine molluscan fauna of the Hawaiian Islands. - E. ALISON KAY
Cenozoic history of Indo-Pacific and other warm-water elements in the marine Mollusca of New Zealand. -

CHARLES A. FLEMING

Mass production of molluscs by means of rearing larvae in tanks. -

TAKEO IMAI

Cytological relationships of some Pacific Gastropods. -

J. B. BURCH

Characteristics and origin of archibenthal molluscan fauna on the Pacific Coast of Honshu, Japan. -

T. OKUTANI

MK

Natural History of Marine Animals.

by G. E. MACGINITIE and NETTIE MACGINITIE.

McGraw-Hill Book Company, New York, 1968. pp. xii + 523; frontisp. + 286 figs. in text (line drawing and halftone illustrations). Second Edition.

The authors are well-known naturalists who have devoted together more than one human life span to the loving study of the marine animals. It seems almost superfluous to say anything about this second edition, at least as far as the many users of the first edition are concerned, except, perhaps, to mention that various portions of the book have been rewritten to include the results of more recent findings. However, as is the earlier edition, so is this one eminently readable, though there is no avoiding of technical terminology where needed. As the authors have intended, the book is useful to a beginning nature-lover as well as to the teacher of marine biology. In these days when molecular biology is the vogue - we almost said, the fashion - it is good to see a book again that deals with the entire living organism in its many facets. It is unnecessary to enumerate the various chapters into which the book is divided; the appendices, occupying 40 or so pages, are, however, worth a special mention.

RS

American Opisthobranch Mollusks

by EVELINE MARCUS and ERNST MARCUS.

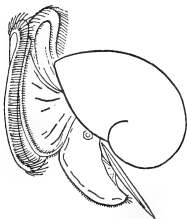
Studies in Tropical Oceanography No. 6. Institute of Marine Sciences, University of Miami, Florida. December 1967. pp. viii + 256; 1 color plate; 155 + 92 line drawings in text. Clothbound, \$7.50.

The book is divided into two sections. The first portion deals with 62 species of mollusks from Florida, the West Indies, the Pacific side of the Panama Canal Zone, and from Brazil. The second portion deals with 47 species of mollusks, mostly, if not exclusively, from the northern Gulf of California.

In all, 40 new taxa are described on the species and subspecies level and 2 on the generic level; 3 replacement names are introduced.

The authors have devoted many extremely productive years to the study of mollusks in general and to opisthobranchs in particular. The present work reflects the rich background in the knowledge possessed by the authors. In view of the modern trend in secondary schooling to neglect the teaching of the so-called classical languages, it might be regretted that the authors steadfastly refuse to give the etymology of the names they choose or coin. Aside from this slight flaw, the work appears to come up to the usual standards of these well known workers. It is unequivocally an important contribution to the knowledge of a beautiful group of animals.

RS



THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable.

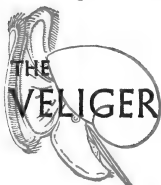
It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

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Short original papers, not exceeding 500 words, may be published in the column "NOTES and NEWS"; in this column will also appear notices of meetings of regional, national and international malacological organizations, such as A. M. U., U. M. E., W. S. M., etc., as well as news items which are deemed of interest to our Members and subscribers in general. Articles on "METHODS and TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, and PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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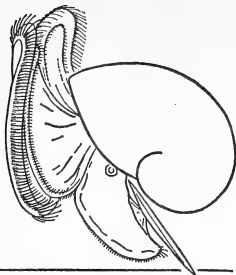
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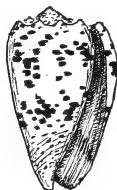
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples, and by increasing indentation.

ORDER, Suborder, DIVISION, Subdivision, SECTION,
 SUPERFAMILY, FAMILY, Subfamily, Genus, (Subgenus)
New Taxa

Five New Species of Mitridae from the Indian and Pacific Oceans

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 11)

INTRODUCTION

DURING THE PAST SEVERAL YEARS a number of unknown mitrids from widespread localities have come to my attention from several sources. At least five of these seem to be unquestionably new species. Three of them were first encountered during my visit to Western Australia in 1966; the fourth was a single specimen from Easter Island given to me perhaps a dozen years ago by Raymond L. Summers of Petaluma, California; and the final species, from Coron, Philippine Islands, was recently sent to me for identification by Fernando G. Dayrit of Manila. All five will be described here.

ACKNOWLEDGMENT

I am grateful for the valuable assistance of all of the individuals and institutions mentioned herein. In addition, I should like to thank Dr. Takeo Suzuki for his expert help in processing my film, and Crawford Cate for many less tangible kinds of aid.

1. In October 1966, Alexander Gilbertson of Geraldton, Western Australia showed me the collection of miscellaneous shells he has put together during several years of lobster fishing and dredging in the vicinity of the Abohos Islands, some 50 miles offshore from his home base. Among these shells I noticed a species of mitrid I had never seen before; later, though it was his only specimen, Mr. Gilbertson very generously presented it to me for my own collection. About a week later, while working in the mitrid collection at the Western Australian Museum upon the invitation of its Curator of Molluscs, Dr. Barry Wilson, I found an almost identical shell from a different

locality some 250 miles to the south of the Abohos Islands. To the best of my knowledge these are the only two specimens of this species now known.

Pterygia gilbertsoni J. CATE, spec. nov.

(Plate 11, Figures 1a - 1d)

Shell large, solid, heavy, cylindrically ovate, ventricose, light tan in color, mottled and vaguely axially striped with irregular white "flames". Sutures moderately impressed and lightly crenulated; spire slightly less than half the length of the shell. Whorls convex, numbering 8, plus $1\frac{1}{2}$ nuclear whorls; apex slightly eroded in both known specimens. Surface of earliest whorls decussate with numerous axial grooves and about 3 smooth, shallow spiral grooves; body whorl with 3 distinct spiral grooves at shoulder and about 8 additional irregularly-spaced, very shallowly impressed spiral grooves on body whorl to base of shell; in the paratype these are somewhat stronger than in the holotype, and appear as darker brown, faintly incised lines. Aperture about twice as long as spire, straight; labrum in the holotype thin (immature); in the paratype thick, simple and with barely perceptible callus-nodes at end-points of incised spiral lines of body whorl. Columella, aperture and lip porcelain-white. Columella calloused, with 5 to 6 prominent oblique folds; anterior canal short, straight.

Discussion: *Pterygia gilbertsoni* is somewhat similar to *P. hayashii* (KURA, 1959), a rare form from Japan. It differs from that species by its lack of axial spots and punctate spiral sculpture throughout, both of these characters being prominent in *P. hayashii*. *Pterygia gilbertsoni* differs from *P. nucea* (GMELIN, 1791) by its more produced spire, its faintly incised spiral sculpture which is lacking in *P. nucea*, its straight lip (flaring in *P. nucea*), and the

apparent lack of a periostracum, which is blackish and fairly heavy in *P. nucea*. *Pterygia gilbertsoni* differs from *P. dactylus* (LINNAEUS, 1758) in its more produced spire, its fewer columellar folds and its less flaring lip.

Holotype: No. 1129-67, Western Australian Museum, Perth, Western Australia. Length: 46.4 mm; Width: 18.9 mm; Length of Aperture: 28.7 mm. Collected 5 miles west of NW end of Rottnest Island in 19½ fms, on sand and dead coral substrate. Leg. Hawo, 5/7/60.

Paratype: No. 12379 in coll. Jean M. Cate, Los Angeles, California, U. S. A. Length: 51.6 mm; Width: 20.4 mm; Length of Aperture: 32.7 mm. Dredged in 24 fms on coral bottom, ½ mile NE of Eaglesnest Island, Easter Group, Abrolhos Islands, Western Australia, July 1963. Leg. Alexander Sutton Gilbertson, a crayfisherman residing at Geraldton; the new species is named in his honor.

Type Locality: Off Rottnest Island, near Fremantle, Western Australia in 19 fms (Lat. 32°00' S; Long. 115°30' W). The known range at present is from Rottnest Island to the Easter Group of the Abrolhos Islands, a span of 4°32'.

2. By an interesting coincidence, the other new species from Western Australia also seems to belong to the comparatively small genus *Pterygia* RÖDING, 1798. It is represented by a unique specimen now in the collection of the Western Australian Museum at Perth.

Pterygia barrywilsoni J. CATE, spec. nov.

(Plate 11, Figures 2 a, 2 b)

Shell large, heavy, solid; cylindrically ovate, ventricose. Sutures moderately impressed, spire less than half the length of shell. Whorls convex, numbering 7 plus 1 nuclear whorl which is somewhat worn. All whorls marked by closely punctate spiral grooves, about 21 on the body whorl and 7 on the penultimate whorl. Columella whitish, with 4 prominent rust-colored oblique folds. Color of shell off-white, with prominent brownish-gray to yellowish irregular flame-like axial markings; base of shell rust colored. Two fairly narrow white transverse zones appear at about mid-point of dorsum, though these are not so clearly defined on ventral side.

Discussion: *Pterygia barrywilsoni* somewhat resembles *P. gilbertsoni*, but has a rougher, rather chalky texture whereas *P. gilbertsoni* appears smooth and shining. *Pterygia barrywilsoni* has a distinctive surface ornament, a much more developed punctate sculpture, and a vivid coloration not present in other *Pterygia* species. The original museum label indicates that this specimen had

been misidentified as *Scabricola sphaerulata* (= *S. papilio* (LINK, 1808)), an error brought about evidently through the combination of color and pattern which are remotely similar to that species; however, *P. barrywilsoni* quite definitely seems to fall within the subfamily Cyliodromitridae and in the genus *Pterygia* because of its short spire and general shell shape. The soft parts and radula are unknown.

Holotype: No. 334-66 in the Western Australian Museum, Perth, Western Australia. Length: 38.9 mm; Width: 15.5 mm; Length of Aperture: 23.0 mm. Collected at Nightcliff, Darwin, Northern Territory, Australia. Leg. Jo Cunningham, 1962.

Type Locality: Darwin, Northern Territory, Australia (Lat. 12°20' S; Long. 130°59' E).

This new species has been named for Dr. Barry R. Wilson, Curator of Molluscs at the Western Australian Museum, in recognition of his pioneering activities in the field of malacology on the west coast of Australia.

3. The third new species to come to my attention in the Western Australian Museum Collection is not from Australian waters, but from the Sulu Sea area near Borneo, where it was collected by the Pele-Sulu Expedition of 1964. Specimens from that expedition were shared with the museum at Perth because its Curator of Molluscs, Dr. Barry Wilson, accompanied the expedition as a collector. The type lot consists of 14 shells, which will be shared with other appropriate museums of Dr. Wilson's choice.

Vexillum sitangkaianum J. CATE, spec. nov.

(Plate 11, Figures 3 a, 3 b)

Shell long, slender, fusiform, somewhat turriculate; spire shorter than body whorl. Protoconch deviated, paucispiral, transparent glassy brown; teleoconch consisting of 10 flatly convex abutting whorls plus 1½ nuclear whorls. Axial sculpture of prominent smooth collabral costae (10 to 11) on penultimate whorl which tend to become obsolete near outer lip; costae not regularly aligned at sutures. Spiral ornament of equidistant shallowly incised grooves, 3 on spire whorls, about 15 on body whorl, faintly granulate on neck. Aperture straight, siphonal canal short and slightly recurved. Labrum relatively thin, simple, flattened in the middle, constricted at base, numerous faint irregular lirae within. Columella straight, with 4 strong oblique posterior folds and one weak fold anteriorly; peristome continuous. Siphonal fasciole weakly produced, heliccone nonumbilicate.

Shell color pure white throughout except protoconch, which is glassy brown. Protoconch present only in Paratype 7, eroded in others. Weak, colorless periostracum present in some specimens. Animal and radula unknown. **Discussion:** *Vexillum sitangkaianum* most closely resembles *V. vulpecula* (LINNAEUS, 1758), but differs from that species in the following ways: it has a more slender and tapering spire, more shouldered whorls, a more constricted base, a flattened and more constricted outer lip, fewer axial costae and a total absence of color or surface ornament.

Holotype: No. 1230-67 in the Western Australian Museum, Perth, Western Australia. Collected by the Pele-Sulu Expedition in 9 to 13 fms, South Lagoon, Sitangkai, Sibutu Island in the southernmost part of the Sulu Archipelago, northwestern Celebes Sea, March 25, 1964.

MEASUREMENTS OF THE TYPE LOT

(in millimeters)

	Height	Maximum Diameter	Length of Aperture
Holotype	34.2	13.3	20.4
Paratype 1	31.6	11.8	17.2
Paratype 2	25.7	9.2	14.1
Paratype 3	25.6	9.3	14.6
Paratype 4	25.5	9.7	15.8
Paratype 5	24.3	9.4	14.5
Paratype 6	24.1	8.5	13.6
Paratype 7 ¹	23.3	9.1	14.3
Paratype 8	23.1	8.9	13.8
Paratype 9	23.0	7.9	13.0
Paratype 10	22.3	10.1	15.9
Paratype 11	20.4	7.4	11.2
Paratype 12	20.0	8.9	12.1
Paratype 13	19.6	7.3	11.7

¹ with protoconch

Type Locality: 9 to 13 fms, South Lagoon, Sitangkai (Lat. 4°50' N; Long. 119°50' E). The range of the species is unknown, as the type lot represents the only specimens known to me at this time.

The specific name *sitangkaianum* is derived from the name of the type locality.

4. The fourth new species under discussion was collected at Easter Island in the southeast Pacific Ocean by Father Sebastian Englert in 1955; he sent a number of specimens to Raymond Summers, who divided them among several

collections. One shell was sent to me, 4 went to the California Academy of Sciences, and it is believed that additional specimens were sent to the U. S. National Museum, the American Museum of Natural History, and possibly to other museums as well; no records were kept of where they were sent. The 5 specimens now in California (those at the California Academy of Sciences and in my own collection) will be enumerated as the type lot; I have not seen the shells sent elsewhere by Mr. Summers.

Strigatella rapanuensis J. CATE, spec. nov.

(Plate 11, Figures 4a, 4b)

Shell small, cylindrically ovate, nearly smooth; whorls slightly convex, numbering 5 including the body whorl, nucleus lacking; spire less than half the length of shell; sutures impressed; labrum thick, smooth, slightly reflected in the middle, flaring at base; columella with 4½ oblique folds; anterior canal very short, straight; color dark yellowish-tan with approximately equidistant deep chocolate-brown, minutely punctate spiral stripes; one pale ochre band appears in center of spire-whorls and 2 near base of shell; interior of aperture and columella glossy white. A periostracum may be present in living examples. Animal and radula unknown.

Discussion: *Strigatella rapanuensis* superficially resembles *Mitra vexillum* REEVE, 1844 because of its similar size and the general color and pattern. It differs, however, in that the stripes are not deeply incised as in *M. vexillum*, instead being smooth, though minutely punctate; *S. rapanuensis* has a lower spire, a strigatelliform outline, and a glazed white aperture, all of which are lacking in *M. vexillum*.

The species is tentatively assigned to the genus *Strigatella* on the basis of its reflected lip, and its general outline and color which conform to the typical characters of that genus; however, further research is needed to determine whether this placement is correct. Among the Strigatellas it most closely resembles *S. tristis* (BRODERIP, 1836) from the Panamic Province, but the presence of the striped pattern and a lack of a whitish band below the sutures, among other characters, mark it as clearly different from *S. tristis*.

Holotype: No. CAS 13103 in the California Academy of Sciences Geology Department Type Collection, San Francisco, California. Leg. Father Sebastian Englert, 1955.

Paratypes: Paratypes 1 to 3 in the California Academy of Sciences Geology Department Type Collection (CAS 13104, 13105, 13106), San Francisco, California. Para-

type 4 in the collection of Jean M. Cate, Los Angeles, California (No. 12380).

MEASUREMENTS OF THE TYPE LOT
(in millimeters)

	Height	Maximum Diameter	Length of Aperture
Holotype	25.0	11.9	15.7
Paratype 1	22.1	10.4	15.7
Paratype 2	22.7	10.8	14.4
Paratype 3	21.4	10.8	14.4
Paratype 4	24.3	11.3	15.6

Type Locality: Easter Island (Rapa Nui), south Pacific Ocean (Lat. 29°00' S; Long. 109°30' W). The specific name *rapanuiensis* is derived from the local name for the type locality. The range of the species is unknown, as the type lot constitutes the only specimens of record at present.

Addendum: My conviction that the single specimen I received nearly a dozen years ago was a valid new species now seems to be borne out by the discovery of at least 9 additional specimens (including the 4 at the California Academy of Sciences). I have recently verified that the American Museum of Natural History has at least one specimen (W. E. Old, Jr., personal communication). After the species description was in manuscript I received 4 additional shells as a further gift from Mr. Summers; these had been collected by Father Englert (presumably at the same locality) in 1965 — ten years later than the original lot. I have not included the measurements of these specimens with those of the type lot, but note that they all fall within the size range listed above. It is likely, from Mr. Summers' recollections, that specimens of *Strigatella rapanuiensis* exist in the collection at the U. S. National Museum and possibly others as well.

5. The final new species to be described is a small, colorful shell from the southern Philippines; it is represented by two nearly identical specimens.

Vexillum coronense J. CATE, spec. nov.

(Plate 11, Figures 5a, 5b)

Shell small, slender, fusiform, somewhat turriculate; spire about the same height as the body whorl. Protoconch lacking in both known specimens; teleoconch consists of 8 flatly convex whorls. Axial sculpture of 10 prominent costae (11 to 12 on penultimate whorl) which are not regularly aligned at sutures. Sutures impressed; spiral ornament consists of numerous equidistant shallowly incised transverse grooves (15 on body whorl) in intercostal interstices, becoming nearly obsolete over ribs. Aperture straight, siphonal canal short and slightly recurved. Neck of shell, starting at first posterior columellar fold, is coarsely ribbed, granulose. Labrum thin, simple, constricted at base, with numerous faint irregular lirae within. Columella straight, with 3 strong oblique folds posteriorly and 1 very weak fold anteriorly. Siphonal fasciole weakly produced, helicocone nonumbilicate.

Shell color bright, deep orange except neck and columella which are both porcelain-white. First 4 whorls bear narrow white spiral bands; final 2 to 3 whorls are surrounded by a fainter orange band at periphery. Animal and radula unknown.

Discussion: *Vexillum coronense* is so markedly different from any other species known to me that it was difficult to select a species for diagnostic comparison. Almost arbitrarily I have chosen *V. moana* J. CATE, 1963 because of its similarity in coloration and construction at the base of the shell; the sharply defined rugose white base is striking in both species. Otherwise, however, *V. coronense* and *V. moana* differ markedly, *V. coronense* being more slenderly tapering and having an altogether different sculpture, surface ornament and color.

In overall shape *Vexillum coronense* more closely resembles *V. intertaeniatum* (SOWERBY, 1874), but that species lacks the interstitial spiral sculpture, is not constricted at the base, has a greater number of axial costae and bears a different type of surface ornament. The color of *V. coronense* recalls the brilliant orange of *V. taeniatum* (LAMARCK, 1811), but is perhaps a shade or two deeper and richer in color than *V. taeniatum*.

Explanation of Plate 11

Figures 1a, 1b: Holotype, *Pterygia gilbertsoni*, spec. nov. (ca. $\times 1$)
Figures 1c, 1d: Paratype, *Pterygia gilbertsoni*, spec. nov. ($\times 1$)
Figures 2a, 2b: Holotype, *Pterygia barrywilsoni*, spec. nov. ($\times 1\frac{1}{2}$)

Figure 3a, 3b: Holotype, *Vexillum sitangkianum*, spec. nov. ($\times 1\frac{1}{2}$)
Figures 4a, 4b: Holotype, *Strigatella rapanuiensis*, spec. nov. ($\times 2$)
Figures 5a, 5b: Holotype, *Vexillum coronense*, spec. nov. ($\times 3$)



Figure 1 a



Figure 1 b



Figure 1 c



Figure 1 d



Figure 2 a

Figure 2 b

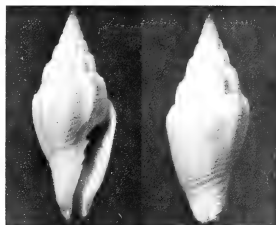


Figure 3 a

Figure 3 b



Figure 4 a



Figure 4 b



Figure 5 a



Figure 5 b

Holotype: No. 13112 in the California Academy of Sciences Geology Department Type Collection, San Francisco, California. Length: 16.7 mm; Width: 6.0 mm; Length of Aperture: 8.3 mm.

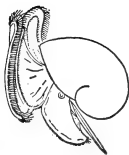
Paratype: No. 12382 in collection of Jean M. Cate, Los Angeles, California.

Type Locality: Coron Island, Calamian Group, Philippine Islands (Lat. 12°10' N; Long. 120°13' E).

The specific name *coronense* is derived from the name of the type locality.

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Archidoris odhneri (MACFARLAND, 1966) comb. nov.,
With some Comments on the Species of the Genus
on the Pacific Coast of North America

BY

ROBERT BURN

Honorary Associate in Conchology
National Museum of Victoria, Melbourne, Victoria

IN HIS MAGNIFICENT memorial volume on the Opisthobranchia of the Pacific Coast of North America (1966), the late FRANK MACE MACFARLAND introduced many new species with minutely detailed descriptions and beautifully executed plates, both in colour and pen and wash. The validity and synonymy of the new species is a desideratum for students of the opisthobranch molluscs the world over and remains an important task for competent Pacific Coast researchers. In some instances, the generic placement of species is open to question. The present contribution, though very short, presents the case for the generic transfer of one species.

Within the large family Dorididae, often the only criteria for generic separation are found in differences of the reproductive systems. Thus, genera have been founded upon the armature or its absence in the male and female ducts, the presence of a prostate gland whether discrete, a mere dilation or its absence, and the formation of the spermatheca and spermatocyst in their modes of attachment to the vagina and uterine duct and in their relationship to one another. In the subfamily Doridinae (ODHNER, 1939: 26, 27; = Doridinae plus Archidori-dinae of ODHNER, 1926: 54), the external and pharyngeal differences between some genera are so slight that only careful examination of the reproductive organs can indicate the true generic position. Thus in the following text, considerable emphasis is placed on the various parts of the reproductive organs.

Austroboris odhneri MACFARLAND, 1966 (173-179; plt. 26; plt. 29, fig. 14; plt. 36, figs. 1-19) is a large apparently rare dorid from the Monterey Bay region of California. MACFARLAND (pp. 171-173) gave a generic definition, noted that his species was the first of the genus from the northern hemisphere, and tabled the valid and reputed species of the genus. The writer has recently examined 3 species of *Austroboris* from Austral-

ian Antarctica as well as 2 species of *Archidoris* from New Zealand and Heard Island (an Australian dependency in the subantarctic Indian Ocean), during which time a survey of the literature of these 2 genera was made.

Austroboris ODHNER, 1926 (p. 55) is defined as having (1) the winding vas deferens of uniform diameter without prostate gland or prostatic section, and enclosed within a tough leathery sheath for its whole length, (2) no penis or penial armature, and (3) the spermatheca and spermatocyst in vaginal combination. Almost all knowledge of *Austroboris* is contained in two papers (ODHNER, 1926, 1934) where good figures of the reproductive systems of various species are given.

Study of MACFARLAND's figure (1966: plt. 36, fig. 7) shows that *Austroboris odhneri* has (1) the vas deferens at first wider and coiled, then much narrower and winding tortuously within a long broad sheath of fibrous tissue, (2) the former terminating in a low wide penial papilla, and (3) the spermatheca and spermatocyst in semiserial combination.

As these reproductive differences are of generic value, *Austroboris odhneri* cannot be maintained in *Austroboris*.

However, this species does closely resemble *Archidoris wellingtonensis* (ABRAHAM, 1877, p. 259) from New Zealand in which (1) the vas deferens is at first narrow and neatly coiled in a glomerate mass, then wider and straighter as it passes through the long broad sheath of fibrous tissue, (2) there is a low wide penial papilla, and (3) the spermatheca and spermatocyst are in semiserial combination. Hence the writer believes *Austroboris odhneri* and *Archidoris wellingtonensis* to be congeneric and the former to belong to *Archidoris* BERGH, 1878, where it will be known by the new combination *Archidoris odhneri* (MACFARLAND, 1966).

On the other hand, the reproductive system of *Archidoris montereyensis* (COOPER, 1862) (MACFARLAND, 1966, p. 181), a common species of the Pacific Coast from Alaska to San Diego (STEINBERG, 1963: 70), differs considerably from *A. odhneri* in that there is a very distinctive digitiform penis and the spermatheca and spermatocyst, while still semiserally combined, lie very close together. These reproductive characteristics are also present in specimens of *A. kerguelensis* BERGH, 1884 (p. 85) from Heard Island. It seems therefore that a re-appraisal of generic and subgeneric units is necessary for these species of *Archidoris*, but this must await comparative examinations with specimens of the type species of the genus, *Archidoris tuberculata* (CUVIER, 1804).

Furthermore, it should be pointed out that MARCUS, 1961 (p. 16) appears to have confused *Archidoris odhneri* and *Archidoris montereyensis*. His figure of the reproductive system (plt. 3, fig. 55) suggests by the spacing of the spermatheca and spermatocyst and the absence of a distinct penis that he examined small specimens of *Archidoris odhneri*.

Two other species of *Archidoris* are reported from the Pacific Coast of North America. The first is *A. tuberculata* (CUVIER, 1804) to which there are but two references. In the "Albatross" report on the dredgings along and off the American west coasts, BERGH (1894: 158) gives a brief description of some Atlantic specimens of *A. tuberculata*, and in a separate paragraph (p. 159) records a single specimen from off La Paz, Baja California (24°11' N, 109°55' W) in 10 fathoms. It was somewhat like *A. montereyensis* in colour and shape of the radular teeth though these were rather more numerous in number of rows and teeth per half row (formula 56 x 84-084). This specimen was 21 mm long, 14 mm broad and 9 mm high. BERGH was quite familiar with *A. tuberculata* from European and eastern Atlantic waters with its distinctive patterning of larger tubercles set among more numerous smaller tubercles (ALDER & HANCOCK, 1854; Family 1, plt. 3, figs. 1-2, 6). As this specimen had a radular formula within the range of that species, he no doubt considered it identical. O'DONOGHUE (1926, p. 207) recorded this specimen as *Archidoris britannica* (JOHNSTON, 1838).

Shortly afterwards, BERGH (1900: 221) recorded a smaller specimen from Bare Island (between Vancouver Island and the Canadian mainland) which he also identified with *Archidoris tuberculata*. It was only 13 mm long, 8 mm broad and 4 mm high with the radular formula 29 x 37-037. In this specimen the number of teeth per row is half that of European specimens, hence the identification must be regarded as rather uncertain.

Zoogeographically, it is possible that *Archidoris tuberculata* should occur on both coasts of North America. Already there are several nudibranch species with this distribution, viz. *Aeolidia papillosa* (LINNAEUS, 1761), *Onchidoris bilamellata* (LINNAEUS, 1767), *Dendronotus frondosus* (ASCANIUS, 1774) (MARCUS, 1961: 56-57). These 3 species also occur in Hokkaido, northern Japan (BABA, 1957) and *A. tuberculata* is recorded from far eastern Russian seas (VOLODSCHENKO, 1941: 60; 1955: p. 183; plt. 48, fig. 5).

ABRAHAM's specimens from Vancouver Island, listed as *Doris tuberculata* (1877: 198), were examined by O'DONOGHUE (1926: 206, footnote) who found them to be identical with *Archidoris montereyensis*.

The last species of *Archidoris* is *A. nyctea* BERGH, 1900 (p. 222) from Bare Island. It is known only from a single 50 mm long specimen with small (2 mm diameter) and smaller rounded tubercles and 8 branchiae. The radula of 37 x 70-070 is both very close in formula and shape of teeth to *A. montereyensis*. Similarly, the reproductive organs with the vas deferens coiled into a twisted mass and the semiserial spermatheca and spermatocyst each with a long duct, are very close to *A. montereyensis* (MACFARLAND, 1966: 182; plt. 37, figs. 9, 10). BERGH appears not to have examined *A. montereyensis* in detail (1878: 624; 1879: 107) except for the radula, hence when confronted with reasonably fresh material in which a spurious rhachidian tooth occurred, he preferred to create a new species instead of referring it to the former. Until it can be shown otherwise, the writer believes that *A. nyctea* should be maintained among the synonymy of *A. montereyensis*. O'DONOGHUE (1921: 154; 1926: 206) does not mention *A. nyctea* as a separate species nor list it among the synonymy of any other species.

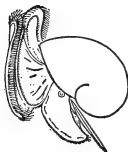
To summarize, there are four points:

1. Study of various figures of reproductive systems show that *Austrodothis odhneri* MACFARLAND, 1966 is untenable in that genus and must be transferred to *Archidoris* in the new combination *Archidoris odhneri* (MACFARLAND, 1966).
2. Three species of *Archidoris* occur on the Pacific Coast of North America: *A. montereyensis* (COOPER, 1862) with low bluntly conical small tubercles of uniform size is widespread and common; *A. odhneri* (MACFARLAND, 1966) with low large and small tubercles is rarer and probably often confused with the first; and *A. tuberculata* (CUVIER, 1804) with larger tubercles set in a field of smaller tubercles is reported from 2 internally differing specimens.
3. *Archidoris nyctea* BERGH, 1900 is most probably a junior synonym of *A. montereyensis*; its only distinction is a spurious rhachidian in the radula.

4. *Archidoris tuberculata* from Baja California and Bare Island needs to be re-discovered and compared directly with European specimens. The Bare Island specimen may be only a small *A. montereyensis* with somewhat reduced radula; that from Baja California may represent an extra-limital southern form of the same species in which the radula has evolved a greater number of teeth.

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Quantitative Studies on the Cowries (Cypraeidae) of the Allan Hancock Foundation Collections

BY

GERALD J. BAKUS

Allan Hancock Foundation, University of Southern California, Los Angeles, California 90007¹

THE CYPRAEIDAE OF THE ALLAN HANCOCK Foundation Collections consist of shells and preserved specimens taken during the Hancock Pacific and Atlantic Expeditions (see FRASER, 1943; GARTH, 1945). The remainder of the collection includes cowrie shells collected from the Indo-Pacific by various persons. Because information obtained on Hancock Expedition-collected Cypraeidae is detailed, quantitative studies were made on these specimens. Most cowries included in this paper are presently on loan to the Los Angeles County Museum of Natural History under the care of Dr. James H. McLean, Curator of Invertebrate Zoology. For convenience, the order of presentation of information is as follows: 1) Panamic Region; 2) Caribbean Region; and 3) Indo-Pacific Region. Continental and insular geographical distribution of Hancock Panamic and Caribbean Cypraeidae is discussed alphabetically by species. Quantitative information is summarized in Table 1, using standard statistical tests found in BAILEY (1959) and SIMPSON *et al.* (1963). Hancock station number, latitude and longitude are indicated in parentheses. Distributions, habitats, and shell measurements are based on mature specimens unless otherwise indicated. Hancock Indo-Pacific species are listed alphabetically. Raw data and detailed records of Hancock Cypraeidae are on file in the Hancock Foundation. The living Cypraeidae of the western hemisphere, including data on certain meristic characters, are discussed in INGRAM (1951). A more recent summary of Panamic cowrie distribution is given by KEEN (1958) and EMERSON & OLD (1963), and that of Caribbean cowrie distribution by WARMKE & ABBOTT (1961). Mollusks of the Galapagos Archipelago are covered in part by HERTLEIN & STRONG (1955) and the Galapagos Cypraeidae by INGRAM (1948).

PANAMIC CYPRAEIDAE

1. *Cypraea (Erosaria) albuginosa* GRAY, 1825

Localities: San Francisquito Bay, Gulf of California (AHF 531-36; 28°25'55" N and 112°53'30" W) south to Braithwaite Bay, Socorro Island, Mexico (AHF 128-34; 18°42'45" N and 110°56'50" W); Bahia Honda, Panama (AHF 247-34; 7°43'32" N and 81°32'19" W) south to Port Utria, Colombia (AHF 419-35; 5°59'10" N and 77°21'20" W) and Sullivan Bay, James Island, Galapagos Archipelago (AHF 796-38; 00°17'00" S and 90°35'13" W).

Specimens examined: 26 adults and 1 immature; 1 adult specimen is preserved (AHF 2601-54).

Remarks: Data from the Hancock Collections support KEEN's (1958) statement that this species has a discontinuous distribution, i. e., between the mid-Gulf of California and Socorro Island (Hancock data) and Manzanillo, Mexico (McLean, pers. communic.) and from Panama to Ecuador and the Galapagos. There is no significant difference in adult shell lengths between the northern and southern populations ('Student's' *t*-test: $P > 0.05$).

2. *Cypraea (Zonaria) annettae* DALL, 1909

Localities: Tepoca Bay, Sonora, Gulf of California (AHF 1077-40; 30°15'45" N and 112°53'20" W) and Puerto Refugio, Angel de la Guarda, Gulf of California (AHF 1049-40; 29°32'47" N and 113°34'35" W) south to Agua Verde Bay, Gulf of California (AHF 655-37; 25°31'00" N and 111°01'45" W) and San Gabriel Bay, Espiritu Santo Island, Gulf of California (AHF 634-37; 24°25'25" N and 110°20'55" W).

Specimens examined: 46 adults and 17 immatures.

3. *Cypraea (Zonaria) arabicula* LAMARCK, 1811

Localities: Isabel Island, Gulf of California (AHF 124-33; 21°51'30" N and 105°53'35" W) and west of islets off Navidad Head, Tenacatita Bay, Mexico (AHF

¹ Allan Hancock Foundation Contribution No. 313

275-34; 19°12'50" N and 104°49'48" W) south to La Plata Island, Ecuador (AHF 22-33; 01°16'00" S and 81°05'10" W) and west of Manta, Ecuador (AHF 403-35; 00°56'43" S and 80°44'43" W).

Specimens examined: 38 adults and 24 immatures; 1 adult specimen is preserved (AHF 2596-54).

4. *Cypraea (Macrocyprea) cervinella* KIENER, 1843

Localities: Isabel Island, South of Mazatlan, Mexico (AHF 278-34; 21°51'30" N and 105°53'35" W) and Tenacatita Bay, Mexico (AHF 272-34; 19°16'38" N and 104°50'35" W) south to the Galapagos Archipelago (6 stations) and west of Manta, Ecuador (AHF 403-35; 00°56'43" S and 80°44'43" W).

Specimens examined: 29 adults and 58 immatures.

5. *Cypraea (Luria) isabellamexicana* STEARNS, 1893

Localities: Secas Islands, Panama (AHF 867-38; 07°57' 10" N and 82°00'45" W) south to Sullivan Bay, James Island, Galapagos Archipelago (AHF 796-38; 00°17' 00" S and 90°35'13" W).

Specimens examined: 4 adults.

Remarks: SHASKY (1961) reported collecting 3 living specimens of this species near Guaymas, Sonora, Mexico. McLean (personal communication) says that it occurs with relative frequency around Cape San Lucas, Baja California.

6. *Cypraea (Zonaria) nigropunctata* GRAY, 1828

Localities: Jicarita Island, Panama (AHF 243-34; 07° 12'50" N and 81°48'05" W) south to the Galapagos Archipelago (15 stations).

Specimens examined: 26 adults and 18 immatures.

7. *Cypraea (Zonaria) robertsi* HIDALGO, 1906

Localities: Puerto Culebra, Costa Rica (AHF 115-33; 10°25'20" N and 85°40'20" W) south to Port Utria, Colombia (AHF 413-35; 5°59'10" N and 77°21'20" W) and off North Point, Gorgona Island, Colombia (AHF 409-35; 3°02'00" N and 78°10'30" W).

Specimens examined: 15 adults and 3 immatures.

8. *Cypraea (Zonaria) spadicea* SWAINSON, 1823

Localities: South of San Miguel Island, California (AHF 894-38; 34°01'00" N and 120°24'00" W) and Portuguese Bend, California (AHF 1446-42; 33°44'10" N 118°22'06" W) south to mouth of Rio Santo Tomas, outer Baja California (AHF 1595-47; 32° N and 117° W) and Melpomene Cove, Guadalupe Island (AHF 1920-49; 28°51'03" N and 118°17'43" W).

Specimens examined: 47 adults and 2 immatures.

Remarks: SMITH (1962) reported the collection of 20 specimens off Cypress Point, Monterey County, California, at a depth of 80 feet (24 m).

9. *Cypraea (Blasicrura) teres* GMELIN, 1791

Localities: Secas Islands, Panama (AHF 447-35; 07°57' 10" N and 82°00'45" W) south to Bahia Honda, Panama (AHF 247-34; 07°43'32" N and 81°32'19" W).

Specimens examined: 2 adults.

Remarks: The specimen taken at Bahia Honda, Panama, represents the first record of this Indo-Pacific species from the Pacific American coast, so far as is known. The first report from the Galapagos Archipelago (beach, Puerto Grande, San Salvador Island) was that of EMERSON & OLD (1965).

ATLANTIC CYPRAEIDAE

1. *Cypraea (Luria) cinerea* GMELIN, 1791

Localities: Punta Arenas, Joyuda, Puerto Rico (Mattox 92); Punta Basora, Aruba, Netherlands West Indies (A 16-39); and Buccoo Reef, Tabago Island, British West Indies (A 41-39).

Specimens examined: 9 adults; 5 of these are preserved (A 41-39).

2. *Cypraea (Erosaria) spurca* LINNAEUS, 1758

Localities: Outside Caledonia Bay, Panama (A 10-39), Cabo Mala Pascua, Puerto Rico (Mattox 137), and southwest of San Nicolaas Bay, Aruba, Netherlands West Indies (A 18-39).

Specimens examined: 7 adults; 1 specimen is preserved (A 18-39).

3. *Cypraea (Macrocyprea) zebra* LINNAEUS, 1758

Localities: Rincon, Puerto Rico (Mattox 88).

Specimens examined: 1 adult and 1 immature.

INDO-PACIFIC CYPRAEIDAE

The number of shells examined for each species is placed in parenthesis.

1. *Cypraea (Monetaria) annulus* LINNAEUS, 1758 (503)

2. *Cypraea (Mauritia) arabica* LINNAEUS, 1758 (35)

3. *Cypraea (Palmadusta) artuffeli* JOUSSEAUME, 1876 (2)

4. *Cypraea (Erosaria) caputserpentis* LINNAEUS, 1758 (49)

5. *Cypraea (Cypraea) carneola* LINNAEUS, 1758 (3)

6. *Cypraea (Erronea) caurica* LINNAEUS, 1758 (2)

7. *Cypraea (Bistolida) coxeni* COX, 1873 (4)

8. *Cypraea (Mauritia) depressa* GRAY, 1824 (8)

9. *Cypraea (Mauritia) depressa* GRAY, 1824 (8)

9. *Cypraea (Erosaria) erosa* LINNAEUS, 1758 (20)

10. *Cypraea (Erronea) erronea* LINNAEUS, 1758 (11)

11. *Cypraea (Erronea) felina* GMELIN, 1791 (1)

12. *Cypraea (Palmadusta) gracilis* GASKOIN, 1848 (14)
13. *Cypraea (Erosaria) helvola* LINNAEUS, 1758 (14)
14. *Cypraea (Bistolida) hirundo* LINNAEUS, 1758 (5)
15. *Cypraea (Luria) isabella* LINNAEUS, 1758 (12)
16. *Cypraea (Erosaria) labrolineata* GASKOIN, 1848 (5)
17. *Cypraea (Cypraea) lynx* LINNAEUS, 1758 (18)
18. *Cypraea (Palmadusta) lutea* GMELIN, 1791 (1)
19. *Cypraea (Mauritia) maculifera* SCHILDER, 1932 (7)
20. *Cypraea (Erosaria) miliaris* GMELIN, 1791 (5)
21. *Cypraea (Monetaria) moneta* LINNAEUS, 1758 (492)
22. *Cypraea (Erronea) onyx* LINNAEUS, 1758 (7)
23. *Cypraea (Bistolida) pallidula* GASKOIN, 1849 (3)
24. *Cypraea (Erosaria) poraria* LINNAEUS, 1758 (1)
25. *Cypraea (Bistolida) quadrimaculata* GRAY, 1824 (1)
26. *Cypraea (Mauritia) scurra* GMELIN, 1791 (1)
27. *Cypraea (Talparia) talpa* LINNAEUS, 1758 (1)
28. *Cypraea (Cypraea) tigris* LINNAEUS, 1758 (5)
29. *Cypraea (Cypraea) vitellus* LINNAEUS, 1758 (7)
30. *Cypraea (Erronea) walkeri* SOWERBY, 1832 (2)
31. *Pustularia (Pustularia) cicercula* (LINNAEUS, 1758) (1)
32. *Pustularia (Pustularia) globulus* (LINNAEUS, 1758) (1)
33. *Staphylaea (Staphylaea) limacina* (LAMARCK, 1810) (3)
34. *Staphylaea (Staphylaea) nucleus* (LINNAEUS, 1758) (7)
35. *Staphylaea (Staphylaea) staphylaea* (LINNAEUS, 1758) (2)

DISCUSSION

The discontinuous distribution of *Cypraea albuginosa* has been narrowed, but reasons for the discontinuity are obscure. It is assumed that geographical isolation, if genuine, may have taken place in relatively recent geological history because the meristic and ornamental features of shells in the two populations are similar. Geographical isolation may have originated during Pleistocene periods of wandering isotherms (see BANDY, 1967). SCHILDER & SCHILDER (1938) consider the two populations to be different races, but this decision is questionable according to INGRAM (1951) and quantitative data from the present author.

Cypraea teres is reported from the Pacific coast of the Americas for the first time, so far as is known. From present data on habitat affinity and information on Cypraeidae from eastern Pacific Islands (EMERSON & OLD, 1965), it is suggested that this Indo-Pacific species may live on the Pacific coast of Central America in very small numbers because of the absence, with few exceptions, of

coral reefs. EMERSON (1967) noted that 47% of the Clipperton Island (atoll) molluscan fauna has Indo-Pacific affinities and concluded that the present impoverishment of coral reef habitat would appear to be the primary factor that limits establishment of Indo-Pacific mollusks in the Panamic region. I agree with EMERSON and would add that lack of coral reefs would also imply possible lack of specific foods preferred by Indo-Pacific mollusks. Moreover, complex spatial heterogeneity (e.g., coral reefs) would appear to be an important factor in the maintenance of high species diversity since it provides numerous physical "niches" and this would offer the potential for frequent biological interactions. Some of the major reasons why Panamic animals have not been successful in invading the Indo-Pacific region include patterns of ocean currents, brief larval periods, competition (BRIGGS, 1967), and in the case of Panamic cowries, their affinity for non-coral hard substrates (see below).

An analysis of Table 1 provides certain insights into cowrie populations. Caution should be taken since the number of stations and specimens is somewhat low and approximately equal effort and time in collecting cowries were not allotted to each of the habitats. All Panamic cowries were collected more frequently on rock than on coral and several species showed no significant affinity for coral over sand. This suggests that most Panamic cowries may not be well adapted to the coral reef habitat, something quite different from that of many Indo-Pacific Cypraeidae. Moreover, those Panamic species with close Indo-Pacific affinities (i.e., *Cypraea isabellamexicana* and *C. teres*) may have the most restricted habitat preferences but the data are insufficient to support this hypothesis. *Cypraea albuginosa*, *C. robertsi* and *C. spadicea* show the greatest affinity for marine plants. Whether this is indirectly related to feeding specificity is unknown. *Cypraea albuginosa* and *C. spadicea* show the greatest depth distribution and *C. cervinetta* the least, since the latter species was collected at 28 shore stations from a total of 29 stations. Mean adult shell lengths are greatest in *C. cervinetta* and least in *C. albuginosa* and *C. robertsi*. Shell lengths of the vicariate (very closely related) species *C. cervinetta* and its Caribbean counterpart *C. zebra* are similar although sufficient data are lacking for the latter species. Confidence in the position of mean shell length is greatest in *C. annettae* and least in *C. cervinetta*. All species (with data calculated) show a somewhat high degree of variation in shell length with *C. robertsi* the most variable and *C. cervinetta* the least variable for their respective sizes. The statistics present here, with the exception of certain coefficients of variation, compare favorably with those of SCHILDER & SCHILDER (1966) for the same species. Data from the present study serve to

Table 1
Habitat, depth, and shell length of cowries (*Cypraea*)
from the Pacific and Atlantic Hancock Expeditions

Species	Habitat (% association): total number of stations	rock and other hard substrata	rock and sand	sand	coral	mud	shell	sand and <i>Zostera</i>	coralline algae	fleshy algae
<i>Cypraea</i>										
<i>albuginosa</i>	22	35%	18%	4%	21%	-	4%	-	11%	7%
<i>annettae</i>	28	55%	14%	10%	7%	10%	7%	-	-	-
<i>arabacula</i>	20	73%	9%	4%	14%	-	-	-	-	-
<i>cervinella</i>	29	67%	7%	13%	10%	-	3%	-	-	-
<i>cinerea</i> ¹	3	2 stations	-	-	1 station	-	-	-	-	-
<i>isabellamexicana</i>	3	2 stations	-	-	1 station	-	-	-	-	-
<i>nigropunctata</i>	17	83%	11%	-	6%	-	-	-	-	-
<i>robertsi</i>	10	62%	-	8%	7%	-	-	-	23%	-
<i>spadicea</i>	27	55%	7%	21%	-	-	-	7%	-	10%
<i>spurca</i> ¹	3	-	-	-	1 station	1 station	-	-	-	-
<i>teres</i>	2	-	-	-	2 stations	-	-	-	-	-
<i>zebra</i> ¹	1	-	-	-	-	-	-	-	-	-

provide information necessary for partial interpretation of population structure. What is needed are specific data on age and sex distribution, natality per female, mortality, and considerably greater emphasis on ecological aspects such as specific habitat affinity and feeding habits. Because cowries are thought to be rather specialized carnivores, feeding on ascidians (GRAHAM, 1955), detailed knowledge of food and habitat should provide a logical basis for successful discovery leading to thorough biological studies.

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Table 1

Habitat, depth, and shell length of cowries (*Cypraea*)
from the Pacific and Atlantic Hancock Expeditions

	depth range & mean (in m) [] number shore stations	adult shell length and mean (in mm) [] no. shells measured	adult shell length standard deviation (\pm mm)	adult shell length standard error (mm)	adult shell length confidence limits (mm) P = 0.05	adult shell length coefficient of variation
<i>Cypraea</i>						
<i>albuginosa</i>	0-18-93 to 274 [13]	15-22-31 [26]	3.61	22 \pm 0.14	22 \pm 1.39	16.41
<i>annettae</i>	0-5-38 [20]	25-37-47 [46]	4.45	37 \pm 0.65	37 \pm 1.04	12.03
<i>arabacula</i>	0- 3-46 to 64 [18]	17-23-29 [38]	3.78	23 \pm 0.79	23 \pm 1.20	16.43
<i>cervincta</i>	0- 1-46 [28]	39-69-89 [29] *	7.49	69 \pm 0.90	69 \pm 2.72	10.86
<i>cinerea</i>	shore	21-26-34 [9]	-	-	-	-
<i>isabellamexicana</i>	shore	29-37-43 [3]	-	-	-	-
<i>nigropunctata</i>	0- 4-28 to 37 [14]	22-27-37 [26]	4.56	27 \pm 0.88	27 \pm 1.75	16.89
<i>robertsi</i>	0- 4-37 [8]	17-22-28 [15]	4.27	22 \pm 0.28	22 \pm 2.16	19.41
<i>spadicea</i>	0- 7-91 to 93 [21] ³	30-45-57 [47]	5.95	45 \pm 0.89	45 \pm 1.70	13.22
<i>spurca</i>	0 to 44	17-19-25 [7]	-	-	-	-
<i>teres</i>	shallow water	23 and 26 [2]	-	-	-	-
<i>zebra</i>	littoral	68 [1] ⁴	-	-	-	-

* Caribbean species

³ AHF 48-33 (immature shell) measures 79 mm in length

³ Two shells (AHF 2049-51) were collected from a mud bottom at a depth of 60+m in San Pedro Channel, southern California

⁴ An immature shell (Mattox 88) measures 74 mm in length

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An Additional Record for *Cypraea teres* in the Galápagos Islands

BY

WILLIAM K. EMERSON

AND

WILLIAM E. OLD, Jr.

Department of Living Invertebrates
American Museum of Natural History

Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 12)

IN A PREVIOUS PAPER on the marine mollusks of the Galápagos Islands (EMERSON & OLD, 1965), we reported the first records for the Indo-Pacific species, *Cypraea (Talostolida) teres* GMELIN, 1791, in these islands. One large, nearly complete, beach specimen (A.M.N.H. No. 110483) had been obtained at Puerto Grande, Isla San Cristobal (not Isla San Salvador, as we erroneously stated). A second dead specimen, which was mentioned in our report, is now known to have been found by Mrs. Jacqueline De Roy in a fathom of water in Academy Bay, Isla Santa Cruz.

A third specimen has since been found by Mrs. Carmen Angermeyer. It is a glossy, fresh, dead-collected specimen obtained at Sombrero, Isla San Salvador at a depth of 2 fathoms (Plate 12, Figures 7 to 9). This specimen, which is in the Angermeyer collection, is the largest example of this species that we have seen, having a length of 50 mm and a height of 22.7 mm. The specimen from Puerto Grande, although not complete, measures 46.2 mm in length and 20.7 mm in height. The largest example of this species recorded by SCHILDER & SCHILDER (1964, p. 8) is a specimen in the British Museum (Natural History) measuring 45 mm in length. No locality was cited for it.

Dr. E. Alison Kay kindly examined our Galapagan specimens and she confirmed our identification. She com-

mented (*in litteris*) that the specimen from Isla San Salvador was the largest that she had seen with the possible exception of a large fragment representing the dorsal part of a shell that was dredged off Kihei Lagoon, Maui, Hawaiian Islands, which is in the collection of Dr. C. M. Burgess. According to Dr. Kay, the fragment fits over the dorsum of the largest Galapagan specimen, and she concludes that the Hawaiian specimen must have been nearly 50 mm in length. She pointed out, however, that all other specimens she has seen from the Hawaiian Archipelago, including Midway Island, do not exceed a maximum of 35 mm in length. We have found the larger Galapagan specimen to be about 10 mm greater in length than the largest specimen with data in the 50 lots from throughout the Indo-Pacific region contained in the collection of the American Museum.

In this widely ranging Indo-Pacific species, the shells exhibit two distinct forms that apparently represent sexual dimorphism. In the larger inflated form, presumably the female, a maximum length of about 36 mm is most commonly encountered. The smaller, less globose shells of the apparent males, rarely attain a maximum length greater than 30 mm. A similar dimorphic condition exists in the population occurring at Clipperton Island, the only other record for this species in the eastern Pacific. The

Explanation of Plate 12

Figures 1 to 3: *Cypraea (Talostolida) teres pellucens* MELVILL, 1888, Secas Island, Panama, 7°57'10"N, 82°00'45"W, shallow water, coral, 1935 (A. H. F. 447-35; Frazer, 1943); × 1.3

Figures 4 to 6: *Cypraea (Talostolida) teres pellucens* MELVILL, 1888, off Fort Kamehameha, Oahu, Hawaii, shallow water, C. M. Burgess coll. (A. M. N. H. 91898, ex-Burgess); × 1.3

Figures 7 to 9: *Cypraea (Talostolida) teres* GMELIN, 1791 (s. l.), off Sombrero, Isla San Salvador [James Island], Galápagos Islands, in 1 fm, Angermeyer collection; × 1



Figure 1

Figure 2

Figure 3



Figure 4

Figure 5

Figure 6



Figure 7

Figure 8

Figure 9

largest specimen we have seen from this oceanic island is 35 mm in length, and these specimens are typical of examples from populations occurring in the Hawaiian Archipelago and Central Pacific that have been recognized as a subspecies, *Cypraea (Talostolida) teres pellucens* MELVILL, 1888. A specimen from Oahu, Hawaii (A. M. N. H. No. 91898; *ex* Burgess) is illustrated for comparison (see Plate 12, Figures 4 to 6).

As one might expect giant specimens to occur in isolated, peripheral areas of a widely ranging species, we believe, on the basis of our limited Galapagan sample, that it is prudent to consider these insular specimens a large growth form of *Cypraea teres* s.l. that does not merit subspecific recognition. Additional collecting may demonstrate, however, that the Galapagan population is unique.

ADDENDUM

After the text for this manuscript was completed, BAKUS (1968, p. 94, this issue) cited specimens of *Cypraea teres* from west Panama, the first known records for this taxon on the continental shelf of the New World. These specimens, one from Secas Island and one from Bahía Honda in the Gulf of Panama, were obtained by the Allan Hancock Pacific Expeditions more than 30 years ago.

Through the courtesy of Drs. Gerald J. Bakus and James H. McLean these specimens were examined by us, and they were found to be the small, narrow form, presumably males. The specimens appear to be referable to the subspecies *Cypraea (Talostolida) teres pellucens* MELVILL, which is known to occur in the eastern Pacific at Clipperton Island. The Panamanian specimens were collected alive in association with stony corals, apparently the same habitat occupied by this species at Clipperton Island (HERTLEIN & ALLISON, 1960). The larger of the 2 Panamanian specimens, which is nearly an inch less in length than the largest of the Galapagan specimens, is here illustrated (Plate 12, Figures 1 to 3). The smaller specimen from Panama (A. H. F. Station 247-34; FRASER, 1943), measures 22.7 mm in length, 12.3 mm in width, and 9.5 mm in height; it is a more mature individual than the larger, figured specimen.

The discovery of this Indo-Pacific species in the Gulf of Panama, although belatedly recorded, serves to demonstrate once again our limited knowledge of the faunas associated with the isolated coral reefs occurring in the southern part of the Panamic Province (EMERSON, 1967). Additional specimens of this species complex are required from the eastern Pacific in order to compare

them with populations from the Hawaiian Archipelago and the western Polynesian islands before the taxonomic significance of the large Galapagan specimens can be determined more critically.

ACKNOWLEDGMENTS

In addition to Mesdames Carmen Angermeyer and Jacqueline De Roy of Academy Bay, Isla Santa Cruz, Galápagos Islands, we are indebted to the following individuals for courtesies of various kinds: Dr. E. Alison Kay of the University of Hawaii, Honolulu and Dr. C. M. Burgess of Honolulu, Hawaii; Dr. James H. McLean of the Los Angeles County Museum of Natural History, Los Angeles, and Dr. Gerald J. Bakus of the Allan Hancock Foundation, University of Southern California, Los Angeles, California.

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The Egg Masses and Veligers of Southern California Sacoglossan Opisthobranchs

BY

RICHARD W. GREENE

Department of Zoology, University of California, Los Angeles, California 90024

(6 Text figures)

INTRODUCTION

HURST (1967) HAS DEMONSTRATED the importance of egg masses and veliger larvae to the systematics of north-east Pacific opisthobranchs. The present paper deals with the order Sacoglossa as an addition to the work of HURST, and as a contribution to our knowledge of this group. HURST (*op. cit.*) has described the egg mass and veliger of *Olea hansineensis* AGERSBORG, 1923 (Sacoglossa: Oleidae). A brief description of the egg mass of *Hermaeina smithi* MARCUS, 1961 has been given by GONOR (1961), and LANCE (1962) has given a short description of egg masses of *Stiliger fuscovittata* LANCE, 1962 (both Sacoglossa: Hermaeidae).

The animals included in the present study are *Elysia hedgpethi* MARCUS, 1961 (Elysiidae), *Hermaea dendritica* ALDER & HANCOCK, 1846 and *Hermaeina smithi* (Hermaeidae). All three species were collected intertidally in Los Angeles County, California. In order to make the data more useful, the methods used by HURST (1967) for description of egg masses and veligers have been applied.

EGG MASSES

All the egg masses described in this paper belong to the Type B of HURST (1967). They are more or less cylindrical in cross-section through the individual egg bands. When attached to a flat substrate, the masses possess a very thin jelly-free layer, while those found tangled among filamentous algae (*i. e.*, *Chaetomorpha*) have no apparent jelly-free layer.

Elysia hedgpethi (Text figure 1; Tables 1 and 2):

The egg mass of *Elysia hedgpethi* (Figure 1) is in the form of a counter-clockwise spiral. The mass is invariably attached along its entire length to the substrate. In the field the eggs are laid among the fronds of *Codium fragile* HARIOT, 1889, the alga upon which the animal lives and feeds. Individual masses of eggs may range between 4 and 6 mm in diameter. The egg band itself measures between 1 and 2 mm in width depending upon

the size of the spawning animal. The terminal portion of the egg band sometimes encloses several capsules containing no ova. A single ovum is found in each capsule. The entire egg mass is white in color, and the eggs within the band appear randomly distributed in space.

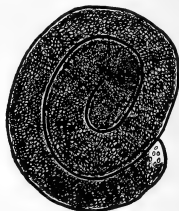


Figure 1

Egg mass of *Elysia hedgpethi*

The pattern of spawning and structure of the egg mass of *Elysia hedgpethi* closely resembles that of *E. maoria* POWELL, 1937 from New Zealand (REID, 1964).

Hermaea dendritica (Text figure 2; Tables 1 and 2):

This species lays an egg mass very similar to that of *Elysia hedgpethi*. The mass is in the form of a counter-clockwise spiral and is found in the field attached to the fronds of *Codium fragile*. When kept in captivity, *Hermaea* may lay thread-like masses along the glass sides of the container. The egg mass of *H. dendritica* is white and is attached to the substrate along its entire length (Figure 2). The eggs are deposited in a spiral within the egg mass which serves to distinguish the egg mass of *H. dendritica* from that of *E. hedgpethi*, which is found on the same alga species.

Table 1
Characteristics of the Egg Masses of Sacoglossans

	Color		Width of egg string		Attachment		2 nd twisting		Veliger type			Days taken Appearance of Veliger	
	White	Yellow	< 1 mm	> 1 mm	Most of length	Other	Present	Absent	Eggs/capsule	Uninflated	Inflated		
<i>Elysia hedgpethi</i>	×		×	×	×		×	×	1	×		14	10
<i>Hermaca dendritica</i>	×	×	×	×	×		×	×	1	×		7-8	5
<i>Hermacina smithi</i>	×	×	×	×	×	×	×	×	1	×		5-6	4

¹ see description

Hermacina smithi (Text figures 3a, 3b; Tables 1 and 2):

The egg masses of *Hermacina smithi* take at least two different forms (Figures 3a and 3b). GONOR (1961) has described masses taking the shape of a "C" with a total length of about 20 mm. These are the most common type found in aquaria when animals are kept in captivity. In the field, however, the masses are deposited as tangled strings among the filaments of *Chaetomorpha acera* KÜTZING, 1849. Tangled strings are also frequently found on the sides of glass aquaria containing *H. smithi*. These masses are a variation on the plano-spiral mass (Figures 1 and 2) and differ in that they are attached to the substrate only at intermittent points along their length (Figure 3b). The C-shaped masses are found either floating on the surface film of the aquarium or are



Figure 2
Egg mass of *Hermaca dendritica*

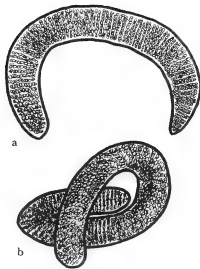
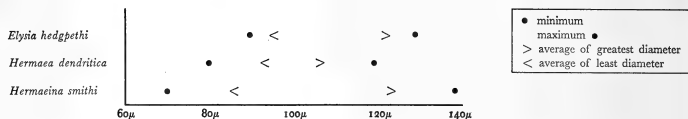


Figure 3
Egg masses of *Hermacina smithi*

attached along their entire length to the glass surface. The egg capsules appear to be arranged in a spiral pattern inside the egg mass.

In addition to the two shapes of egg masses observed, there are also two color types. GONOR (1961), working with specimens from San Juan Island, Washington, has described the eggs as being "lemon-yellow" when spawned, becoming paler with further development. In the present study of *Hermacina smithi* collected in southern California, both yellow and white egg masses were deposited by

Table 2
Egg Capsule Dimensions



adults and were observed through hatching. The yellow masses became visibly paler with development, while the white egg masses remained white.

VELIGER SHELLS

The veliger shells of the three species of sacoglossans studied are of the uninflated type, or Type I. HURST

(1967) discussed at length the difficulties of orienting veliger shells for measurement. Table 1 gives data on development of the egg masses, and Table 3 gives measurement data and length : width : depth ratios for the veliger shells.

Elysia hedgpethi (Text figure 4; Tables 1 and 3):

The veliger shell of *Elysia hedgpethi* resembles that of both other species in the present study in that the only apparent sculpture consists of minute pits over the entire surface of the shell which are visible only under 150 \times magnification. The lip around the aperture is somewhat variable in that the anterior portion may project beyond the rest of the lip (Figure 4a) or may be even with it. In general, the gross shape of the shell seems to be of major importance when comparing it with other species (i. e., Figures 5 and 6).

Hermaea dendritica (Text figure 5; Tables 1 and 3):

Of the species considered in the present study, *Hermaea dendritica* has the roundest of the shells examined. In addition, Figure 5 shows that the posterior portion of the shell is narrower than the anterior portion, and that there is little evidence of coiling externally (Figure 5a). Sculpture consists of small pits as in the other two species.

Hermaeina smithi (Text figure 6; Tables 1 and 3):

The apertural lip on the veliger is commonly flared, though not all shells examined had this appearance (Figure 6). Sculpturing is manifested once again by small pits over the surface of the veliger shell. Of the three species included in the present study, *Hermaeina smithi* shows the greatest degree of coiling on the right side.

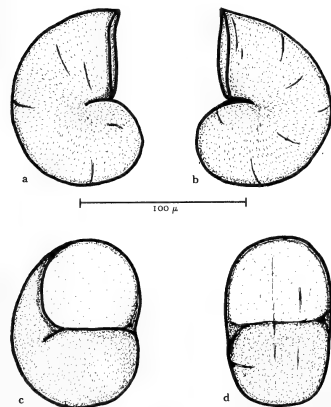


Figure 4

Veliger Shell of *Elysia hedgpethi*

a - right side b - left side c - ventral d - dorsal

DISCUSSION

The usefulness of data on opisthobranch egg masses and veliger larvae has been pointed out by HURST (1967) along with the problems of obtaining such data. THOMPSON (1961) discussed the importance of veliger shells in the classification of sacoglossans.

Table 3
Veliger Shell Dimensions

	Observations	Length	Width	Depth	Ratio L:W:D
<i>Elysia hedgpethi</i>	10	105 μ \pm 20.6	66.1 μ \pm 11.2	77.8 μ \pm 3.1	1.59 : 1 : 1.17
<i>Hermæa dendritica</i>	10	97 μ \pm 15.0	65.5 μ \pm 8.2	71.2 μ \pm 11.2	1.48 : 1 : 1.09
<i>Hermæina smithi</i>	10	109 μ \pm 1.7	69.5 μ \pm 3.6	79.5 μ \pm 6.1	1.57 : 1 : 1.14

maeina smithi are found among the filaments of *Chaetomorpha acraea*, or, as reported by GONOR (1961), among the various algae in the *Enteromorpha* mat. LANCE (1962) shows an egg mass of *Stiliger fuscovittata* attached to *Polysiphonia pacifica* HOLLENBERG, 1942, the alga upon which the animal feeds.

It is interesting to note that the three species of sacoglossans considered all maintain a symbiotic relationship

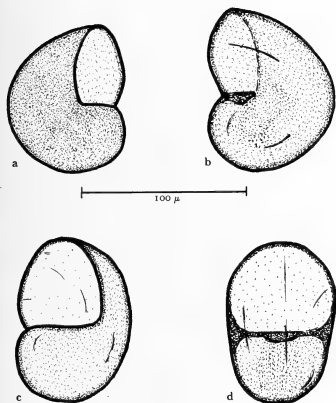


Figure 5

Veliger Shell of *Hermæa dendritica*

a - right side b - left side c - ventral d - dorsal

The egg masses of sacoglossans may be distinguished not only by their gross form and positioning of egg capsules, but also to a great extent by where they are found in the field. Sacoglossan opisthobranchs are found in specific habitats such as fronds of algae and generally leave their eggs on the algal substrate. Thus, eggs of *Elysia hedgpethi* and *Hermæa dendritica* are found on the fronds of *Codium fragile*, while egg masses of *Her-*

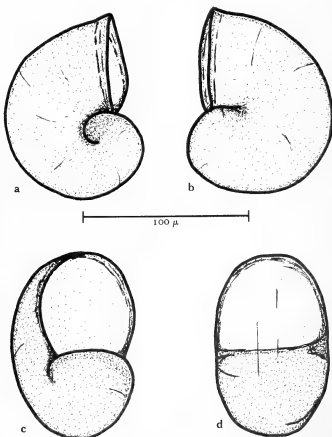


Figure 6

Veliger Shell of *Hermæina smithi*

a - right side b - left side c - ventral d - dorsal

with the chloroplasts of their algal substrate (GREENE, in preparation). The chloroplasts are obtained during feeding and are retained within the cells of the digestive diverticula in a functional condition. The egg masses have been examined for evidence of transmission of chloroplasts from one generation to the next, and the results are negative. The chloroplast symbionts are apparently not obtained until some time after settling and metamorphosis of the veligers.

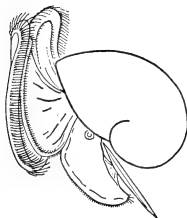
The veliger shells of the species described here are distinguishable by their gross form and dimensions. The shells of all three species are small compared with most of those described by HURST (1967). The egg masses and veliger shells described here correspond well with those described for sacoglossans in other parts of the Pacific Ocean (OSTERGAARD, 1950; REID, 1964).

ACKNOWLEDGMENT

The author wishes to express gratitude to Dr. Leonard Muscatine of the Department of Zoology, University of California at Los Angeles for his critical reading of the manuscript and to James R. Lance for confirmation of identifications of species used in the study.

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A New Species of *Puncturella* (*Cranopsis*) from the Northeastern Pacific

BY

I. McT. COWAN

Department of Zoology, University of British Columbia, Vancouver, Canada

AND

JAMES H. McLEAN

Los Angeles County Museum of Natural History
900 Exposition Boulevard, Los Angeles, California 90007

(Plate 13; 1 Text figure)

WEST AMERICAN SPECIES of the genus *Puncturella* LOWE, 1827, have been treated in a dissertation by McLEAN (1966). We have recently become aware of an undescribed species not covered by McLEAN (op. cit.) and have decided to present a detailed description before the review of the genus is to be published by him.

The subgenus *Cranopsis* A. ADAMS, 1860 (type species, *Cranopsis pelex* A. ADAMS, 1860, Japan), has previously been characterized as applying to species of *Puncturella* having the fissure placed in nearly central position on the anterior face of the shell. McLEAN (op. cit.) showed that a more useful criterion is the presence of a major double rib, extending from the anterior terminus of the fissure to the margin of the shell. The two halves of this rib are connected by a channel showing a distinct line of suture, visible under magnification. In the soft parts of the animal the roof of the mantle cavity is split from the mantle margin to the fissure. The suture on the anterior rib evidently results from the shell being produced by the split mantle margin. In *Puncturella* s. str. the mantle roof is continuous and is perforated only in contact with the fissure of the shell.

West American species heretofore placed in *Puncturella* s. str. but having the above diagnostic features of *Puncturella* (*Cranopsis*) are: *Puncturella* (*C.*) *major* DALL, 1891; *P. (C.) cucullata* (GOULD, 1846); and *P. (C.) multistriata* DALL, 1914.

Puncturella (*Cranopsis*) *decorata* COWAN & McLEAN,
spec. nov.

(Plate 13, Figures 1 to 5; 1 Text figure)

Description of Holotype: Shell of moderate size for the genus; basal outline ovoid, sides nearly parallel, anterior end slightly narrower than the posterior. Width to length ratio 0.74. Anterior outline slightly convex; posterior slightly concave; apex approximately central, strongly down-curved and slightly deflected to the left. Fissure long and narrow with a constricted lower portion. Radial sculpture strong, composed of primary and secondary ribs regularly placed and clearly demarked; primary ribs originating on the apex; secondary ribs originating 2 to 3 mm below; 5 mm below the apex these number 13 ribs (7 primary and 6 secondary) in a 5 mm horizontal distance; secondary ribs precisely equidistant from each primary and nearly equal in strength to the primary ribs at the shell margin. Tertiary ribs originating 5 to 8 mm below the apex, but not reaching the size of the primary and secondary ribs at the margin. Ribs at margin broader than interspaces. The primary rib extending below the fissure is a double rib having a well defined sutural line extending to the margin. This compound rib is slightly deflected toward the right and is broader but not as raised as are the adjacent primary and secondary ribs. Ribs elegantly beaded, deriving from regular horizontal rid-

ges associated with the lines of growth, extending across the sulci as well as over the radial ridges. Numerous minute whitish punctations scattered in the channels between ribs; entire external surface speckled with minute chestnut flakes of what appears to be a cuticle, their abundance giving a brown appearance over the white shell. Inner surface of shell glossy and translucent, transmitting traces of the radial sculpture. Septum in the form of an open arc, slanted forward. Internal groove from fissure to margin clearly defined; margin of shell crenulate, corresponding to extension of the ribbing.

Dimensions: Long. 19.7 mm; lat. 14.5 mm; alt. 10.3 mm.

Type Material: Holotype, National Museum of Canada (NMC), cat. no. 45745 (Plate 13, Figure 1).

Type Locality: Off west coast, Queen Charlotte Island, British Columbia, 53°21.3' N latitude; 133°04.1' W longitude, at a depth of 106 fathoms (193 m). Collected by Mr. Frank Bernard aboard Fisheries Research Board of Canada vessel *G. B. Reed*, Bernard station 67-46, 11 August 1967. Seven additional paratypes of smaller size were taken in the same haul. Two are deposited in the type collection of the Los Angeles County Museum of Natural History (LACM), cat. no. 1175; one in the United States National Museum (USNM), cat. no. 678542; one in the Paleontological type collection of the California Academy of Sciences (CAS), cat. no. 13102; one in the Stanford University Paleontological type collection (SUPTC), cat. no. 9961; and two in the Cowan collection, cat. no. 7283a-b.

Distribution: Localities for additional specimens identified as belonging to this species are as follows:

1) Six specimens, Bjorka Island, near Sitka, Alaska, 56°49' N; 135°50' W; 110-117 fms.; G. McT. Cowan at Fisheries Research Board of Canada Station 66-2-26, 5 September 1966; LACM 6764 a (Plate 13, Figure 2); Cowan coll. 6764b-f;

2) Five specimens, off Cape James, Hope Island, Queen Charlotte Strait, B. C., 85-95 fms.; Cowan sta. 748, Cowan and McLean, 22 May 1963; Cowan coll. 4649a-d; LACM 4649e;

3) Three specimens, south side Matole Canyon, California, 300-100 fms.; *N. B. Scofield* sta. B. 17, 11 October 1950; CAS loc. 33179 (Plate 13, Figure 4);

4) One specimen off west end of San Nicolas Island, California, 30-50 fms., Templeton Crocker Expedition, 27 August 1932; CAS loc. 27603 (Plate 13, Figure 5);

5) One specimen (juvenile), between Cortez and Tanner Banks, California, 80 fms.; Louis Zermatten, April 1965; S. S. Berry coll., Redlands, California, cat. no. 33354 (Plate 13, Figure 3);

6) One specimen, Cortez Bank, California, 60 fms., USFC sta. 2911, USNM 130419.

Table 1

		Specimen No.	Length	Breadth	Height
			(in millimeters)		
NMC	(Fig. 1)	45745	19.7	14.5	10.3
LACM		1175a	11.2	8.4	5.5
LACM		1175b	11.7	8.5	5.4
SUPTC		9961	13.7	9.4	6.4
CAS		13102	13.5	10.4	6.7
USNM		678542	11.4	8.1	5.9
Cowan		7283a	12.8	9.3	5.4
Cowan		7283b	9.0	6.5	4.9
LACM	(Fig. 2)	6764a	13.3	10.0	5.8
Cowan		6764b	12.8	9.0	5.0
Cowan		6764c	17.3	12.0	8.0
Cowan		6764d	11.0	7.9	5.2
Cowan		6764e	13.0	10.8	6.0
Cowan		6764f	9.9	7.1	4.3
Cowan		4649a	15.0	12.3	7.8
Cowan		4649b	15.3	11.0	7.8
Cowan		4649c	10.7	8.4	5.6
Cowan		4649d	10.8	—	5.2
LACM		4649e	10.5	7.4	5.7
CAS	(Fig. 4)	33179a	23.4	17.8	12.8
CAS		33179b	22.9	15.2	10.0
CAS		33179c	—	14.7	8.4
CAS	(Fig. 5)	72603	18.7	13.5	8.5
SSB	(Fig. 3)	33354	6.5	4.5	2.7
Ratio of parameters to length			75%	48%	
			314.1	236.7	159.3

Explanation of Plate 13

Figures 1 to 5: *Puncturella (Cranopsis) decorata* COWAN & McLEAN spec. nov.

Figure 1: Holotype, National Museum of Canada, cat. no. 45745. Off west coast, Queen Charlotte Island, British Columbia, 106 fms. Long. 19.7 mm; lat. 14.5 mm; alt. 10.3 mm; × 2

Figure 2: Off Bjorka Island, near Sitka, Alaska, 110-117 fms. LACM 6764 a. Long. 13.3 mm; lat. 10.0 mm; alt. 5.8 mm; × 2

Figure 3: Between Cortez and Tanner Banks, California, 80 fms. SSB 3354. Long. 6.5 mm; lat. 4.5 mm; alt. 2.7 mm; × 5

Figure 4: South side of Matole Canyon, California, 300-100 fms. CAS 33179a. Long. 23.4 mm; lat. 17.8 mm; alt. 12.8 mm; × 2

Figure 5: Off San Nicolas Island, California, 30-50 fms. CAS 27603. Long. 18.7 mm; lat. 13.5 mm; alt. 8.5 mm; × 2

Figures 6 to 7: *Puncturella (Cranopsis) multistriata* DALL, 1914
Figure 6: Cadboro Bay, Victoria, British Columbia. LACM A.375. Long. 16.6 mm; lat. 12.4 mm; alt. 8.4 mm; × 2

Figure 7: Puget Sound, Washington, dredged. LACM A.8487. Long. 25.0 mm; lat. 20.0 mm; alt. 15.7 mm; × 2

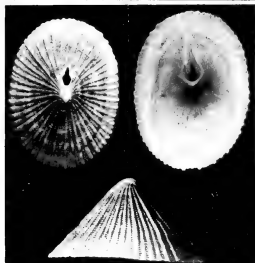


Figure 1

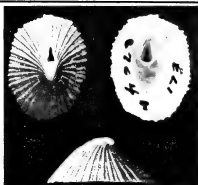


Figure 2



Figure 3

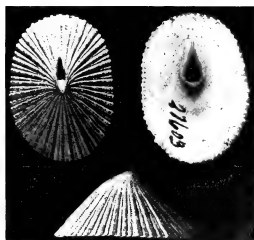


Figure 5

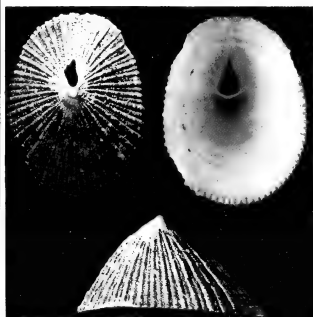


Figure 4

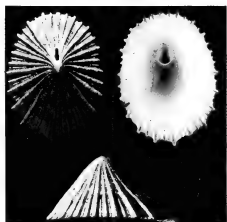


Figure 6

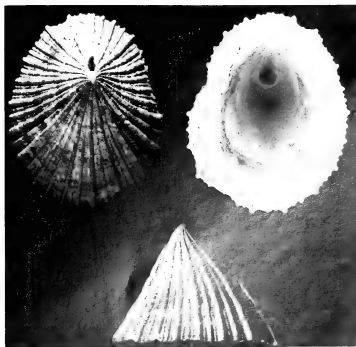


Figure 7

Dimensions: Table 1 gives the external dimensions of 24 specimens of *Puncturella decorata*. Width to length ratio is indicated as 75%, height to length ratio 48%. A corresponding series of 26 *P. multistriata* has the width to length ratio 82%, differing to an insignificant degree but this species is taller, with a height to length ratio of 62%. Regressions of width against length and height against length have been determined for samples of both species. The formulae for the width to length regression of *P. decorata* are $W = 0.771 L - 0.7$, height to length $H = 0.482 L + 0.07$. Equivalent values for *P. multistriata* are $W = 0.758 L - 0.51$ and $H = 0.716 L - 1.753$.

The significance of differences between the corresponding regressions of the two species have been examined by the method suggested by SIMPSON, ROE & LEWONTIN (1960). The probability of significance of the differences between the length-width relationship of the two species is 0.8 to 0.9. The corresponding probability for the length-height relationship is 0.05 to 0.02.

Discussion: The soft parts are not differentiable on the basis of material on hand from other members of the subgenus. The mantle is split from the margin to the fissure. The radula of a paratype specimen (LACM 1175a) has been examined (Text figure 1). The rachidian and 4 adjacent lateral teeth have slightly overhanging edges, while the fifth lateral tooth has a large turned central cusp and a smaller basal cusp. A lateromarginal plate is present and the marginals are numerous. The radula is similar to that of other west American species of *Puncturella*.



Figure 1

Radula of *Puncturella (Cranopsis) decorata* COWAN & McLEAN

The fissure extends nearly half the length of the anterior face of the shell in juvenile specimens (Plate 13, Figure 3), but this area decreases to about one-third to one-fourth of this dimension in mature shells.

The specimens examined are remarkably uniform in sculptural detail. The structure of the internal area adjacent to the septum is variable. A few specimens examined (Plate 13, Figure 2) show slight traces of the buttress structure posterior to the septum, typical of *Puncturella (Puncturella) galeata* (GOULD, 1846). In the subgenus *Cranopsis* this is also a characteristic feature of *P. major* DALL, 1891. Its development in *P. decorata* is considerably less than in either of these species.

The species is closely related to *Puncturella multistriata* DALL, 1914 (Plate 13, Figures 6, 7), which differs chiefly in that the secondary ribs do not attain the size or prominence of the secondary ribs in *P. decorata*. *Puncturella multistriata* sometimes bears distinct series of pits between the vertical ridges of the external sculpture. These can be impressed into the sides of the ridges scalloping their sides, and suggesting beading. However, none bear the regular horizontal ridges, crossing the primary and secondary ribs, as well as the intervening sulci, that give rise to the characteristic beaded sculpture of *P. decorata*. The new species differs also in the position of the apex; it is centrally placed in *P. decorata*, and about one-third the length of the shell from the anterior margin in *P. multistriata*. The upper portion of the fissure is consistently broader than that of *P. multistriata*, whereas in the latter species it is only slightly broader than the lower portion. Specimens of *P. multistriata* have not been found with the buttresses to the septum shown by a few specimens of *P. decorata*. On the basis of specimens examined, *P. multistriata* reaches a much larger size (to 32 mm long), whereas the largest *P. decorata* seen is 23 mm long (Plate 13, Figure 4). In the new species the shell appears to be thinner and more fragile in specimens of similar size.

Different geographic and bathymetric patterns of distribution are indicated for *Puncturella decorata* and *P. multistriata*. *Puncturella multistriata* has been taken in shallow depths from the Aleutian Islands and ranges south to the Puget Sound area, where it has been dredged in depths ranging to 50 fathoms. No verified records of the species are known from south of Puget Sound. DALL's (1921) record of the species "south to San Diego," was based on USNM 211927, not a *P. (Cranopsis)*; and the "Cortez Bank" record (USNM 130419) is *P. decorata*. The known range of *P. decorata* is therefore from Sitka, Alaska, south to Cortez Bank, California. The two species have thus far not been taken at the same collecting station.

ACKNOWLEDGMENTS

We are grateful to Mr. Frank Bernard of the Fisheries Research Board of Canada for making the type material available for our use. Dr. Leo Hertlein of the California Academy of Sciences and Dr. S. Stillman Berry of Redlands, California kindly arranged the loan of specimens. Photographs are by Mr. Armando Solis, Museum Photographer. The radular drawing was prepared by Cathy Pearse.

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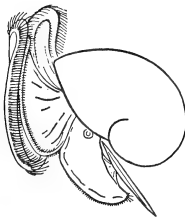
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Studies on Populations of the Cowrie *Erronea erronea* (LINNAEUS)

BY

FRANZ ALFRED SCHILDER

AND

MARIA SCHILDER

University of Halle, German Democratic Republic

(5 Maps; 6 Tables)

Erronea erronea (LINNAEUS, 1758) IS A RATHER common cowrie species distributed throughout the Indo-Pacific Ocean from Ceylon to Samoa and from Japan to the Exmouth Gulf and Sydney (F. A. SCHILDER, 1965, p. 181). The individual variation in many characters of the shell is considerable; nevertheless the differences in the means or medians of different populations often can be demonstrated to be mathematically significant.

Recent examination of far more than 4000 specimens (cf. M. SCHILDER, 1967a, p. 373) has indicated that the geographical races defined 30 years ago (F. A. & M. SCHILDER, 1938, p. 152) can hardly be maintained as taxonomic units. However, our studies demonstrated the existence of an unspotted sympatric mutant living around Broome in Western Australia (F. A. SCHILDER, 1968a, 1968b).

In the present paper we intend to investigate the correlation between the medians of 5 selected characters in 133 natural populations coming from all regions of the inhabited Indo-Pacific Ocean, and the geographical distribution of these medians. These investigations quantitatively far exceed former studies on the same subject published 7 years ago (F. A. & M. SCHILDER, 1961), though localities from which we studied one or very few shells only have been completely disregarded.

CHARACTERS

The following 5 characters have been selected for this study, as their records are most complete in our card registry of all personally examined cowrie shells:

- L = length of the shell in millimeters;
 BL = maximum breadth in % of length, mostly indicating also the degree of callosity of the margins and of the base;
 DB = dorsal central blotch;
 AS = anterior terminal spots; usually the size of the right (labial) spot has been considered only, the few cases excepted in which the left (columellar) spot is larger than the right one;
 BC = color of the base and the unspotted margins; the bluish grey zonate inner lip in rather young specimens has been disregarded.

According to previous papers (e.g. SCHILDER, SCHILDER & HOUSTON, 1964, pp. 158-159, table 2) we have classified each character in 6 classes; Table 1 shows the meaning of the figures 1 to 6 in the following paragraphs.

The convexity of the base, the narrowness of the aperture, and the visibility of the dorsal zones (SCHILDER & HOUSTON,

Table 1

Class	1	2	3	4	5	6
L	17-19	20-21	22-23	24-25	26-28	29-35
BL	53-54	55	56	57	58	59-61
DB	absent	obsolete	small	rather large	large	very large
AS	absent	obsolete	small	rather large	large	very large
BC	white	almost white	yellowish white	pale yellow	rich yellow	orange

1964, table 2) have been omitted because these characters have not been registered in many populations, especially several decades ago; in our earlier paper on *Erronea erronea* we have considered the characters DB and AS only (F.A. & M. SCHILDER, 1961).

A dash (-) in a column indicates that the character has not been recorded in a sufficient way.

POPULATIONS

Table 2 contains the 133 populations considered for the present study, as they comprise a satisfactory number of adult specimens. The 8 columns indicate:

1. the designation of the region and area according to F.A. SCHILDER, 1965, pp. 174-175;
2. the locality; an asterisk (*) indicates populations comprising at least 40 adult specimens;
3. the collector, or if in parentheses, the collection or museum in which the population has been preserved; series collected by the same collector at the same place but at different times have been pooled to a single population;
4. median length (L) in millimeters;
5. median relative breadth (BL) in % of length;
6. median size of dorsal blotch (DB);
7. median size of the anterior spots (AS); and
8. median color of the base (BC), each expressed in classes 1 to 6 as explained in Table 1.

Table 2

			L	BL	DB	AS	BC
15d	Darwin: Lee Pt.	L. Watson	30	56	5	1	3
15b	Sunday Isld.	(Perth)	28	58	5	2	2
	Broome	(Schelechoff)	24	59	3	1	4
	Broome	(Uetz)	27	59	5	1	3
	* Willie Creek	Kalnins	22	59	5	1	3
	* Quandong	Kalnins	22	58	5	1	3
	* Gantheaume Pt.	Kalnins	25	58	5	1	4
	* Black Ledge	Kalnins	26	57	4	1	3
15e	Port Hedland	(Schelechoff)	22	57	4	1	4
	Port Samson	B. Wilson	28	57	4	1	3
	Dampier Arch.	Davena Exp.	22	56	4	1	2
54h	Lord Howe Islds.	(Melbourne)	28	57	4	2	3
47a	Avoca: Norah Head	W. Krause	25	57	-	1	3
47b	Woolgoolga	W. Krause	24	56	4	3	3
	* Moreton Bay	Schelechoff	32	57	4	1	4
	Caloundra	Schelechoff	32	56	5	2	4
	Mooloolaba	Lee & Matcott	24	57	4	2	3
47c	Lady Elliott Isld. "61"	Schelechoff	24	59	3	1	2
	Lady Elliott Isld. "65"	Schelechoff	26	56	3	4	3
	Mast Head Isld.	(Melbourne)	25	56	4	1	2
	* One Tree Isld.	Coucum	25	58	5	1	2
	Heron Isld.	(Melbourne)	22	57	5	1	1
	Tryon Isld.	(Summers)	24	58	5	1	1
	Fitroy Reef	Coucum	28	56	5	1	1
	Humpy Isld.	Coucum	28	56	5	1	3
	* Middle Isld.	Coucum	28	56	5	1	4
	* Pumpkin Isld.	Coucum	26	56	5	2	3
	* North Keppel Isld.	Coucum	26	56	5	1	3
	Conical Isld.	Coucum	29	55	5	2	4
	Piccaninny Pt.	Coucum	30	57	3	3	4
	Double Heads	Coucum	35	55	4	3	3
	Yepoon (before 1954)	(Summers)	30	56	4	2	3
	Yepoon (after 1954)	Rita Mada	30	57	5	3	4
	Seaforth	Matcott	29	60	4	4	4
	Mackay	Matcott	29	57	4	1	4
	Mackay: Shell Pt.	Griffiths	28	58	5	3	3
	Finlayson	Griffiths	26	54	4	1	3
	Shute Harbour	W. Krause	25	57	5	2	3
	* Proscopine: Dingo Bay	(Schelechoff)	23	57	4	3	4
	* Penrith Isld.	Houston	23	57	5	1	3
	* Scawfell Isld.	Houston	20	56	5	1	3
	* Hayman Isld.	Uetz	22	59	5	1	3
47q	Bowen	(Summers)	22	58	1	3	3
	Port Denison	(Tomlin)	32	55	4	1	2
	Port Denison	G. W. Young	30	54	4	1	3
	Gairns	(Schelechoff)	22	59	4	4	5
	Green Isld.	Price	17	56	3	1	1
	Buchans Pt.	Price	26	58	3	2	3
46c	New Caledonia	Bougier	23	56	3	3	4
	New Caledonia	Durand	28	59	4	1	1
	* New Caledonia	Rossiter	24	56	4	5	3
	Anse Vata	Cernohorsky	20	58	3	3	3
	Mondouze: shore	Cernohorsky	20	55	3	5	4
	Mondouze: outer reef	Cernohorsky	19	55	4	4	3
46f	Cuvu	Cernohorsky	21	56	2	4	4
	* Vuda Pt.	Cernohorsky	21	57	3	4	3
	* Vatia Wharf	Cernohorsky	20	55	3	4	3
	Manava Isld.	Cernohorsky	19	56	2	1	3
13m	Tuticorin	Winckworth	32	58	3	2	3
13c	Ceylon	Eulenburg	25	57	1	5	4
	Ceylon	(Steinfurth)	28	56	4	5	4
	Ceylon	Stoliczka	22	55	3	5	4
	Krusadai	Winckworth	24	59	2	4	5
	* Trincomali	Winckworth	24	57	1	5	5
14t	Phuket Isld.	Brandt	21	57	3	4	4
14m	Medan	Hüner	18	55	-	5	-
14a	Andaman Islds.	A. W. King	24	59	5	4	4
	Andaman Islds.	Sandys	23	58	3	3	4
	Aves Isld.	Winckworth	17	-	4	2	5
	Interview Isld.	Winckworth	17	57	4	1	1
	Nankauri	Winckworth	21	-	1	2	4
	* Port Blair	Winckworth	21	57	4	2	5
14s	Pulo Weh	Buitendijk	21	55	-	4	-
	Nias Isld.	Schröder	21	58	4	4	2
	Padang	de Priester	20	56	1	4	4
	Oosthaven	de Priester	22	56	-	5	3
14j	Labuan	de Priester	19	55	4	4	3
	* Tjilat Euren	de Priester	21	56	5	4	3
	Tjilatjap	de Priester	23	58	-	-	-

Table 2 [Continued]

			L	BL	DB	AS	BC
	Caboni	Cernohorsky	21	57	3	3	4
	Nanau-i-Ra	Cernohorsky	19	56	4	3	3
	Vitilevu Bay	Cernohorsky	18	56	3	3	4
	Lodoni	Cernohorsky	18	57	3	3	4
	Bau Isld.	Sixten Bock	20	56	2	2	3
	Namuka	Sixten Bock	22	57	1	3	2
46t	Vavau	Cordeira	26	57	1	4	2
	Haapai	Cordeira	19	56	1	4	4
41s *	Malaita: Ata'a	van der Riet	25	55	4	3	
41b	New Britain: Vuatom	O. Meyer	21	54	3	2	
	New Britain: Ulamona	J. Schneider	19	54	4	2	2
	Admiralty Islds.	(Melbourne)	22	56	4	1	3
41g	Roon Isld.	Deelder	21	53	5	4	3
	Manokwari	Jochim	19	55	4	4	2
48m	Sorong	Barton	20	56	4	4	2
	Sangir Islds.	de Priester	18	55	—	4	—
	Halmahera	Bernstein	25	57	—	—	—
	Menado	de Priester	24	55	—	5	—
	Busak (NW Celebes)	(Leiden)	22	56	4	5	3
*	Amboina	Hoedt	22	55	4	3	3
	Amboina	Koller	22	—	5	4	2
	Amboina	Ledru	23	—	4	1	2
48a	Kaimana (West Irian)	Ahlers	21	55	—	5	2
48t	North Timor	Wienecke	22	55	4	4	—
	Bali	de Priester	24	55	—	4	—
48c	Tijger Islds.	Verdonk	20	55	—	5	—
	Macassar	Semper	32	55	1	4	—
	Macassar	Toxopeus	—	—	4	2	—
*	Gulf of Madjene	van Nisse	20	56	4	5	—
48j	"Indische Zee" (evidently 1 locality)	(Leiden)	21	55	3	4	2
	Madura	Jochim	25	57	4	5	3
	Batavia Bay	de Priester	19	57	4	3	3
	Batavia Bay	id. (Dautzbrg.)	23	—	1	3	—
	Edam Isld.	de Priester	19	56	—	4	—
48s	Singapore	Doria	28	58	4	5	5
	Singapore	Semper	25	55	3	4	—
	Pulo Sakra	Winckworth	26	57	4	4	4
48g	Ko Si-Chang	Orr, Steiner	24	54	5	4	4
*	West of Ban Pe	Brandt	22	56	5	4	3
*	East of Ban Pe	Brandt	23	55	5	4	3
48p	Zamboanga	Semper	25	—	3	4	3
	Bohol: Ubay	Semper	22	55	4	4	2
	Bohol: Panglao	Semper	20	56	5	1	2
	Cebu	Ringe	18	56	3	4	2
	Samar	Jagor	24	61	2	2	4
	Batangas	Tucker	18	56	4	4	4
	Palawan	Clover	19	55	5	4	3
48v	Pulo Condor	Bavay	30	53	3	2	3
49r	Okinawa: Kue	C. Young	21	56	4	3	3
49s	Tosa	Azuma	30	56	4	4	3
42p	Palau Islds.	(Godeffroy)	27	—	4	2	2
	Palau Islds.	Semper	21	54	5	1	2
	Yap Isld.	Volks	22	61	1	3	5
42c	Truk Isld.	M. Hill	22	53	1	2	2

FREQUENCY OF MEDIANS

The frequency of the 6 classes distinguished in the 5 recorded characters is illustrated by Table 3.

Table 3

	1	2	3	4	5	6
L	19	25	28	24	20	16
BL	9	25	37	28	14	12
DB	12	5	24	48	32	—
AS	35	21	22	38	15	—
BC	6	22	50	32	7	—

The extreme classes 1 and 6 are well represented in L and BL because they comprise more millimeters or % than the central classes; in the characters of color, however, the extreme class 6 is never represented as median. In L, BL, and BC the maximum figure is in class 3, whereas in the two characters of markings (DB and AS) there are evidently 2 maxima of each in class 1 (markings mostly absent) and 4 (markings mostly rather large); the intermediate classes 2 and 3 are less frequent.

CORRELATION OF CHARACTERS

The correlation of the medians of various pairs of characters indicated in Table 2 may be illustrated by the 6 squares of Table 4.

(see page 111 for Table 4)

There is no distinct correlation between any pair of the characters tabulated in Table 4. The average greater breadth of populations of medium classes of length than of extreme classes must be regarded as random; there is no correlation in L : DB nor in BL : BC; the slightly negative correlation in DB : AS and in DB : BC also cannot be proved mathematically, as well as the slightly positive correlation in AS : BC. In any case, there is no general parallelism in accumulation of pigment in the 3 characters DB, AS, and BC (see also F.A. & M. SCHILDER, 1961, p. 304).

INDIVIDUAL VARIATION

The individual variation within extreme populations may be illustrated by Table 5; the figures indicate the number of specimens belonging to each class of the character.

Table 4

	length							length							breadth						
	1	2	3	4	5	6		1	2	3	4	5	6		1	2	3	4	5	6	
breadth	6	-	-	4	5	2	1	6	-	-	-	-	-	6	-	-	-	-	-	-	
	5	-	2	4	3	4	1	5	1	5	8	6	8	4	-	-	2	1	3		
	4	3	4	5	7	5	4	4	9	5	10	6	9	8	4	1	3	9	12	2	4
	3	8	9	6	3	7	4	3	4	8	2	4	2	4	3	4	8	19	9	6	3
	2	6	6	5	4	-	4	2	1	2	-	2	-	-	2	3	5	5	2	3	1
	1	1	3	1	1	1	2	1	1	2	5	2	1	1	1	-	-	2	2	1	1
anterior spots	dorsal blotch						dorsal blotch	dorsal blotch						dorsal blotch	anterior spots						
	1	2	3	4	5	6		1	2	3	4	5	6		1	2	3	4	5	6	
	6	-	-	-	-	-		6	-	-	-	-	-		6	-	-	-	-	-	-
	5	2	-	2	6	-		5	2	1	-	4	-		5	2	1	2	2	-	-
	4	4	2	7	13	8		4	4	2	11	8	7		-	4	6	4	9	9	4
	3	4	-	8	8	2		-	3	1	2	7	21		17	-	3	16	9	10	11
basal color	2	2	2	4	8	5	-	2	3	-	3	10	5	-	2	8	4	1	7	1	
	1	-	1	3	13	17	-	1	-	-	1	2	3	-	1	5	-	-	1	-	
	dorsal blotch						dorsal blotch	dorsal blotch						dorsal blotch	anterior spots						
	6	-	-	-	-	-		6	-	-	-	-	-		6	-	-	-	-	-	
	5	2	-	2	6	-		5	2	1	-	4	-		5	2	1	2	2	-	-
	4	4	2	7	13	8		4	4	2	11	8	7		-	4	6	4	9	9	4
3	4	-	8	8	2	-		3	1	2	7	21	17		-	3	16	9	10	11	4
basal color	2	2	2	4	8	5		-	2	3	-	3	10		5	-	2	8	4	1	7
	1	-	1	3	13	17	-	1	-	-	1	2	3	-	1	5	-	-	1	-	

Table 5

		Class					
Charact.	Locality	1	2	3	4	5	6 median
L ¹	Vatia Wharf	48	24	18	4	-	2
	Moreton Bay	-	-	-	-	2	44
BL ¹	Malaita: Ata'a	82	45	32	17	5	2
	Willie Creek	2	4	7	13	20	49
DB	Trincomali	38	20	13	6	2	1
	Hayman Isld.	-	-	8	17	35	4
AS	Black Ledge	54	8	6	9	1	-
	Trincomali	1	4	10	19	32	14
BC	One Tree Isld.	-	79	4	-	-	2
	Port Blair	-	-	6	29	51	21

¹ The individual extremes in the measurable characters are L = 15 to 39 mm and BL = 50 to 65% in the 133 populations.

These figures establish that there are really significant differences between populations. On the other hand, adjacent populations show great resemblance in many characters, even if they live under different ecological conditions. This fact may be illustrated in Table 6 by 4 populations from an area of 41 miles around Broome: the distance between the 4 localities Willie Creek (95 shells), Quandong (74 shells), Gantheaume Point (85 shells), and Black Ledge (80 shells) is about 15, 15, and 11 miles respectively (according to Mr. A. Kalnins); Gantheaume Point is a rocky coast, Black Ledge is a muddy reef (F. A. SCHILDER, 1968 a, 1968 b).

Table 6 shows that the distribution of the 3 characters in color (DB, AS, BC) is very similar in these 4 populations, as it may be caused by a common gene pool in the whole area of 41 miles, whereas the size (L) and

relative breadth (BL) show great local differences which may be influenced by environmental conditions of the habitat. Besides, there is a distinct negative correlation between length and relative breadth in these 4 populations.

Table 6

		1	2	3	4	5	6*
L	Willie Creek	8	24	27	22	13	1
	Quandong	11	14	29	16	4	-
	Gantheaume Pt.	-	16	15	27	23	2
	Black Ledge	-	1	13	15	33	7
BL	Willie Creek	2	4	7	13	20	41
	Quandong	-	2	8	16	20	28
	Gantheaume Pt.	-	1	15	18	21	29
	Black Ledge	3	7	10	21	24	14
DB	Willie Creek	6	4	14	21	38	12
	Quandong	4	8	3	12	32	15
	Gantheaume Pt.	1	2	3	15	47	17
	Black Ledge	9	5	11	19	24	10
AS	Willie Creek	53	9	11	17	4	1
	Quandong	42	9	8	11	4	-
	Gantheaume Pt.	49	5	11	14	6	-
	Black Ledge	54	8	6	9	1	-
BC	Willie Creek	2	12	57	21	2	1
	Quandong	2	13	34	14	10	1
	Gantheaume Pt.	3	11	27	30	13	1
	Black Ledge	1	13	41	20	4	1

* The medians are printed in *italics*.

Sexual differences exist in the relative breadth (BL) only, as according to previous studies the females of *Erronea erronea* are about one class broader than the males, whereas the other characters show no sexual differences (SCHILDER & HOUSTON, 1964, tables 3 and 4).

LOCAL POLYMORPHISM

The only real mutant concerns the sky-blue absolutely unspotted variant living in the populations 26 miles around Broome, but never collected elsewhere (F.A. SCHILDER, 1968 a); it lives with usual specimens of *Erronea erronea* without producing intermediates, and constitutes 1 to 6% in all populations around Broome. This morpho has been called *azurea* SCHILDER (1968 b).

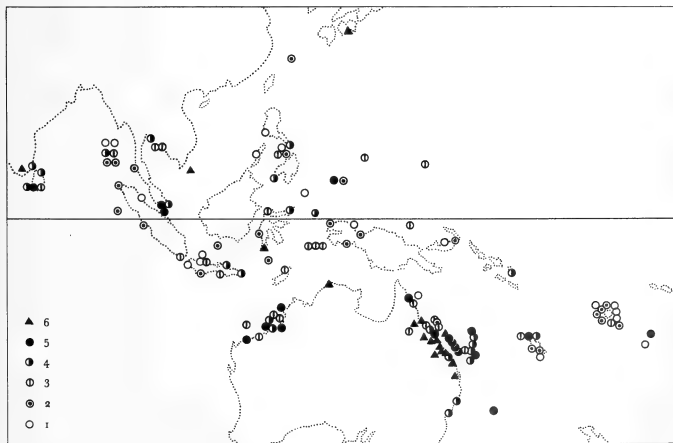
All other extreme varieties, e. g. the substrate melanistic shells (New Caledonia, Pumpkin Island, One Tree Island, etc) or those with the labial anterior spot produced along the margin or even rare shells with one or two posterior terminal spots must be regarded as extreme individual aberrations connected with the normal specimens by many intermediates. Shells showing the dorsum suffused with a layer of unspotted pale enamel should be regarded as pathological, as this accessory layer mostly includes particles of mud or even parasites, and the usual markings are shining through; they occur scattered in

many populations, but seem to accumulate in some populations living under special conditions.

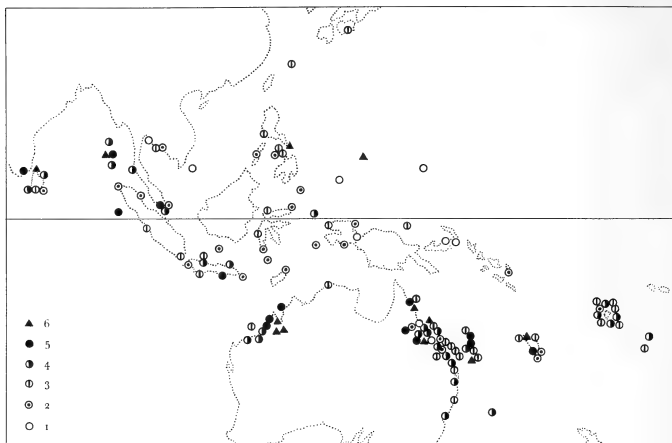
GEOGRAPHICAL DISTRIBUTION OF CHARACTERS

The Maps 1 to 5 illustrate the geographical distribution of the median classes listed in Table 2; the 6 classes of each character have been designated by different symbols progressive in darkness from 1 to 6. Careful examination of these maps will show the following general trends which do not exclude occasional exceptions in one or a few populations.

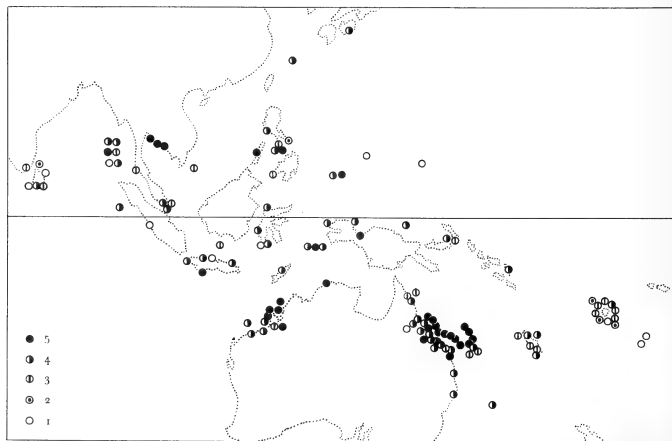
Map 1: Length (L). The smallest *Erronea erronea* live along an approximately equatorial zone from the Andaman Islands to Java, New Guinea, and Fiji; around this zone such populations are mixed with populations of larger specimens, viz. in the West (Ceylon), in the North (north of the line Singapore-Celebes-Palau), and the South (West Australia, East Australia to New Caledonia



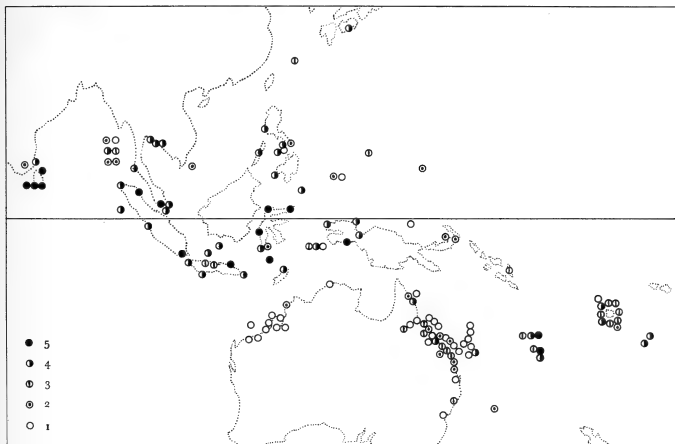
Map 1: Length



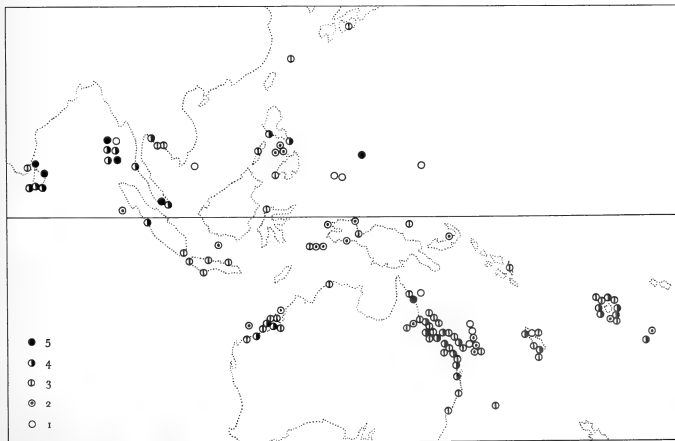
Map 2: Breadth



Map 3: Dorsal Blotch



Map 4: Anterior Spots



Map 5: Basal Color

and Tonga): this arrangement recalls that observed in other cowrie species too (F.A. SCHILDER, 1961, 1962). The largest populations live along the Queensland coast from Mackay to Moreton Bay, while the shells collected at the off-shore islands become smaller by increasing distance (see also F.A. & M. SCHILDER, 1964; M. & F.A. SCHILDER, 1967).

Map 2: Breadth (BL). Mostly narrow populations live in the area between Bali, Solomon Islands, Japan, and Thailand; the western populations ranging from Ceylon to Java are mostly broader, as well as the southern populations from West Australia to Fiji. It is curious that the shells coming from the Keppel Bay Islands are narrower than those from the opposite mainland coast as well as those from the Capricorn Islands farther away from the shore.

Map 3: Dorsal blotch (DB). In the great central area from the Andaman Islands to New Caledonia populations with rather large blotches are mixed with those with reduced blotches; in the farthest West (Ceylon) and the farthest East (Fiji, Tonga) the dorsal blotch is mostly small to absent, as it seems to be in Micronesia also, whereas in the South (i.e. both regions of Australia) the blotches usually are large.

Map 4: Anterior spots (AS). In West Australia the terminal spots are mostly absent, and in East Australia they are small, as well as from the Admiralty Islands to Fiji and Micronesia; in the central zone, i.e. in Tonga and New Caledonia as well as from western New Guinea to Ceylon, these spots are usually well developed to large, though sporadic populations with reduced spots may occur, especially in the Andaman Islands.

Map 5: Basal color (BC). In the populations living in a central zone from Java to the Solomon Islands the base is whitish; this zone may extend northward to Thailand and Japan with few darker populations scattered among many pale ones. In the South from West Australia to Fiji and in the West from Ceylon to Singapore yellow populations are prevalent.

One will observe that in all characters discussed there are widely regional differences in the predominant classes. One could surmise that there is usually a rather equatorial central zone differing from peripheral regions especially in the West and South, and less markedly also in the East and North: so one could summarize the predominant characters as follows:

	Central Zone	Peripheral Regions
L	small	large
BL	narrow	broad
DB	various	N, W, E: small S: large
AS	large	reduced
BC	whitish	yellowish

However, there is no parallelism between the bound-

aries of the regions, because the border lines of the predominant classes of each character cross each other in various ways. Therefore no distinct geographical races can be established by the sum of several characters (F.A. & M. SCHILDER, 1961, p. 305).

Nevertheless, in some restricted areas all or most populations agree in several characters which fact may be explained by a common gene pool influenced by selection in similar environments.

Besides, one will observe that in small islands off-shore, as Dampier Archipelago, Capricorn Islands, Whitsunday Islands, Green Island, Mondoure outer reef, Manava Island, Edam Island, the shells are smaller, narrower, with less developed anterior spots and paler base than in the adjacent coastal populations.

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A New *Neptunea* from the Pacific Northwest

BY

ALLYN G. SMITH

Associate Curator

Department of Invertebrate Zoology, California Academy of Sciences, San Francisco, California 94118

(Plate 14)

FOR MANY YEARS the operations of commercial trawlers along the west coast of North America, particularly off central and northern California and the Pacific Northwest, have been restricted to moderate depths generally not exceeding 100 fathoms and usually in the range of 50 to 75 fathoms. In the last ten years, however, due to offshore fisheries investigations by the California Division of Fish and Game and similar organizations, excellent table fish, such as sole and sablefish (black cod), have been discovered in commercial quantities in much deeper water.

As a result, trawler captains have been lengthening their lines and making successful hauls on new fishing grounds at depths ranging from 100 fathoms to 400 fathoms with the possibility of increasing the range to as deep as 500 fathoms. These deeper-water trawl hauls started early in 1948, when two otter-trawl captains worked their nets in 200 fathoms off the northern California coast and continued to get good results in the 185 to 215 fathom range (HOLMBERG, 1948; SCOFIELD, 1948).

To conchologists fortunate enough to enlist the cooperation of trawl fishermen to save some of the deeper-water mollusks brought up in their nets instead of throwing them back overboard as they usually do, some of the deeper hauls have turned out to be veritable bonanzas. The larger carnivorous mollusks, such as *Neptunea* and *Beringius*, have been turning up more frequently and this has been true also for many smaller species.

Among other mollusks obtained from trawler captains in the last several years by Mr. Everett C. Stiles of Bellingham, Washington, is a new species of *Neptunea* taken sparingly in an area from Cape Flattery, Washington, north to Cape Scott at the northern end of Vancouver Island, British Columbia.

Neptunea stilesi A. G. SMITH, spec. nov.

(Plate 14, Figures 1 to 7)

General Diagnosis: This *Neptunea* is of medium size for the genus and is distinguished mainly by its much

shorter spire compared with other Northwest Pacific species, such as *Neptunea pribilofensis* (DALL, 1919), *N. phoenicea* (DALL, 1891), and *N. lyrata* (Gmelin, 1791). In general shape it is closer to *N. beringiana* (MIDDENDORFF, 1848), which has a smaller, somewhat heavier shell and a geographical range much farther to the north. It has a capacious bodywhorl with an unflared lip when adult, and a short canal. In color it is off-white to beige or yellowish and occasionally a reddish-brown. Major sculpture consists of widely-spaced, moderate to heavy, rounded spiral chords or ribs, which are usually darker in color than the ground-color of the shell.

Description of the Holotype: Shell from an adult living specimen with operculum, of short fusiform shape with a relatively short spire, a large, evenly-rounded, tumid bodywhorl that terminates in a capacious aperture, and a short canal bent slightly to the left and rather sharply to the rear. Divergence of spire (apical angle) approximately 87°. Nuclear whorls damaged at the tip, about 2 remaining, nearly straight-sided, with a small channel near the suture and a low chord below it, otherwise smooth. Postnuclear whorls 4½, rounded, and decorated with a series of evenly-spaced, low, rounded, spiral ribs of which there are 14 on the bodywhorl and 3 each on the preceding postnuclear whorls, with a fourth showing near the suture at the base of the penultimate whorl; uppermost rib weak, the remaining are stronger. The spacing of the spiral ribs becomes gradually wider with the growth of the shell, being 5 to 9 mm apart near their terminations at the peristome. Spaces between the spiral ribs slightly concave and decorated with from 2 to 4 fine spiral chords. Transverse sculpture consists of many, closely-spaced, rather rough lines of growth, overridden by the fine intercalated spiral chords; it is much roughened on the canal. Sutures distinct and slightly channeled; below them the tops of the whorls are slightly flexed, forming a shallow, encircling channel. Outer lip fairly thick, blunt-edged, unflared, somewhat crenulated by the major spiral chords, with a small notch at its anterior terminus with the bodywhorl. Inner lip a smooth wash of callus only. Columella sinuate, terminating on

the canal in a well-marked siphonal fasciole that extends to the tip of the canal. Color of shell cream-white, the major spiral chords a contrasting red-brown. Aperture white, porcellaneous. Operculum heavy, normal for the genus. Periostracum lacking.

Measurements are: length, 93.9; maximum diameter, 64.9; length of aperture (including canal), 71.5; width of aperture, 31.8; length of canal, about 20 mm.

Type Locality and Range: Because of lack of accurate data, no specific type locality can be pinpointed. Most specimens received for study were trawled in depths of approximately 100 to 125 fathoms in the area bounded, in general, on the south by La Perouse Bank, 40 miles west of Cape Flattery, Washington, and on the north by Cape Scott at the northern tip of Vancouver Island, British Columbia. A single specimen was dredged in 34 fathoms, Hakai Pass, British Columbia, by Dr. I. McT. Cowan of the University of British Columbia (UBC No. 1540). Another half-grown shell was also taken by Dr. Cowan in about 85 fathoms, Queen Charlotte Sound, just north of Cape Scott. An old, dead adult specimen in the Stanford University Collection (Department of Geology) was dredged in 110 fathoms, Virago Sound, British Columbia.

Disposition of Specimens: Holotype deposited in the California Academy of Sciences, Geology Type Collection, no. 13124.

Twenty-eight paratype shells have been placed in several institutions, including the California Academy of Sciences, Stanford University, the University of British Columbia, Los Angeles County Museum of Natural History, United States National Museum, and the Academy of Sciences of the U. S. S. R. (Leningrad); and in the private collection of Everett C. Stiles. Preserved animals of 6 paratypes have been deposited in the California Academy of Sciences, Invertebrate Zoology Type series, nos. 371 to 376, inclusive.

Remarks: This fine new species of *Neptunea* is dedicated to Mr. Everett C. Stiles of Bellingham, Washington, whose diligence in enlisting the interest and cooper-

ation of several Pacific Northwest trawler captains has resulted in most of the specimens that have been available to date. Although it is found in the same general area and at about the same depths as the heavily-ribbed *Beringius eyerdami* A. G. SMITH, 1959, it has been taken less frequently and must be rated as a relatively rare species.

In the type lot of 29 shells, 23 were obtained alive, 17 with opercula, although in most instances the animals had disintegrated and could not be saved. There is considerable variation in this series of shells in size, sculpture and color. Size limits are shown by the following measurements:

Dimension	Largest	Smallest
Length, over-all	116.1 mm	69.5 mm
Maximum diameter	72.3 mm	48.6 mm
Length of aperture and canal	78.2 mm	54.4 mm
Width of aperture	35.3 mm	26.4 mm
Length of canal	26.0 mm	8.3 mm
Number of postnuclear whorls	6	3 $\frac{3}{4}$
Apical angle	96°	72°

The most striking sculptural feature is the presence on typical specimens of prominent spiral ribbing of a red-brown color against a cream-white background. This feature is not at all consistent, however. Twenty-eight of the 29 shells can be ranked as follows in terms of the presence and prominence of the spiral ribs or chords:

Ribs obsolete or weak	6
Ribs of medium strength	7
Ribs fairly prominent	15

The shell texture of full-grown adults is only moderately heavy; in younger specimens the shell is quite thin and partially translucent. Older shells have a heavy wash of callus on the inner lip, which makes the peritreme complete. There is no tendency for the outer lip to flare with age or senility. While a small anterior notch, though present, is not especially prominent in the holotype, it

Explanation of Plate 14

Figure 1: *Neptunea stilesi* A. G. SMITH, spec. nov. Holotype, Calif. Acad. Sci. Geol. Type coll. no. 13124. Length: 93.9 mm; maximum diameter: 64.9 mm; apical angle: 83°. Apertural view.

Figure 2: Same, dorsal view.

Figure 3: Enlarged view of the nuclear tip of a subadult paratype from 85 fms, Queen Charlotte Sound, British Columbia. Length (nuclear whorls only): 5.5 mm; maximum diameter: about 3 mm; number of nuclear whorls: 2 $\frac{1}{2}$.

Figure 4: Paratype. Brownish color-form with subobsolete spiral sculpture. Length: 94.3 mm; maximum diameter: 65.8 mm; apical angle: 77°.

Figure 5: Paratype with well-developed spiral ribs. Length: 106.0 mm; maximum diameter: 71.7 mm; apical angle: 92°.

Figure 6: Paratype with somewhat weaker spiral ribs having fine intercalaries between them, stronger on the body-whorl. Length: 106.4 mm; maximum diameter: 69.1 mm; apical angle: 78°.

Figure 7: Radula of paratype animal, Calif. Acad. Sci. Inv. Zool. Type Series no. 371, slide no. 490. Center section, mounted width: 1.1 mm.



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6

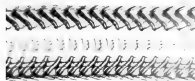


Figure 7

is quite deep in other shells and can be considered as a normal character for the species.

Two shells in the series have complete nuclear whorls. An enlarged view of one of these is shown in Plate 14, Figure 3. It consists of about $2\frac{1}{2}$ smooth whorls with a length of 5.5 mm and a width of about 3 mm. The tip is dome-shaped and folded over on to the second nuclear whorl, which has slightly diverging sides and minutely channeled sutures. This tip broke off during measurement in spite of careful handling; fortunately it could be repaired satisfactorily. This incident developed the fact that while the tip itself was hollow spirally, the beginning of the first postnuclear whorl had already been plugged with shelly material as a protective step preparatory to the loss of the nuclear tip from erosion or other causes. This illustrates why so few *Neptunea* shells of this and other species are collected with their nuclear tips intact.

The normal color-phase is represented in the holotype (Plate 14, Figures 1, 2), which has relatively prominent spiral ribs. Another color-phase is dark red-brown, occurring on 4 shells. Plate 14, Figure 4 shows a smoother form of the latter color although another similar, red-brown shell has relatively heavy spiral ribs marked with a still darker color. A shell with the heaviest, most prominent spiral ribs is shown on Plate 14 in Figure 5, and another with several fine intercalary spirals between the ribs on the upper part of the bodywhorl is shown in Figure 6. The shell apertures are generally pure white inside; however, two have the columella tinted a deep orange-brown with a lighter wash inside the outer lip and in another the entire aperture is colored lavender-pink, edged with white in the vicinity of the peristome.

Animal and Radula: Of the 6 specimens with preserved animals, 2 were males and 4 were females. One of each sex had shells with obsolete ribbing; one male and 3 females had shells with more or less prominent spiral ribs. From this, and from the size and general configuration of the shells, the possible occurrence of any sexual dimorphism in this species is not evident.

The animals (in alcohol) are yellowish-cream color, with occasional black streaks and maculations on the head and foot.

The radula (Plate 14, Figure 7) is typically neptuneid. The central tooth is tricuspid, the central cusp being slightly larger than the other two. The major laterals are also tricuspid, the innermost pair being close together and separated by a narrow V-shaped interval, the innermost cusp being the larger of the two; this pair is separated from the third, narrowly elongate, outer cusp

by a broadly U-shaped interval. Radulae from other animals are not basically different from the one illustrated except for the minor differences that might be expected to occur from age, wear, or individual variation.

Although the available information is somewhat indefinite at present, the species apparently lives on a fairly soft mud bottom. Its egg-capsules have not been identified as yet.

Relationships: *Neptunea stilesi* has no really close relatives. Its short-spined aspect, tumid bodywhorl, and the sculptural characters distinguishes it specifically from other described *Neptunea*, Recent and fossil. Comparison with living species has been made with the work of GOLIKOV (1962, 1963), who has discussed and illustrated those from northern seas in considerable detail; comparison with fossil species was made on the basis of unpublished work of Dr. F. Stearns MacNeil, formerly of the United States Geological Survey.

Neptunea stilesi approaches the shape and in some instances the type of spiral ribbing of *N. beringiana* (MIDDENDORFF, 1848) but the latter has a somewhat smaller-sized, heavier shell and a range extending to the north of the Aleutian chain (GOLIKOV, 1963, fig. 95). Its relationship with other *Neptunea* species occurring off the Pacific Northwest coast is less close as all of them have long-spined shells. Of these, *N. lyrata* (GMELIN, 1791) has heavy spiral keels and a range extending southward into southeast Alaska and northern British Columbia; *N. phoenicia* (DALL, 1891), from British Columbia and Puget Sound, has a dark-brown shell covered with an olivaceous periostracum and a sculpture of rather fine spirals devoid of prominent ribs; *N. pribiloffensis* (DALL, 1919), from the Gulf of Alaska to British Columbia, has more rounded whorls, much deeper sutures, and more closely-spaced, less prominent spiral sculpture; *N. amianta* (DALL, 1889) has a smaller, thinner shell, finely lirated spirally but sometimes with fairly strong spiral keels, and a much deeper habitat ranging from 400 to 1000 fathoms; *N. smirnia* (DALL, 1919), which ranges south off Humboldt Bay, California, has a totally different, larger, smooth, brownish shell with deeper sutures; *N. ithia* (DALL, 1891) is of the same type as *N. smirnia* but is much smaller and has been recorded so far with certainty only in Monterey Bay, California, in 200 to 400 fathoms.

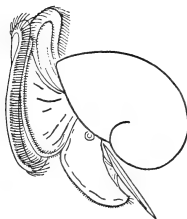
Possibly *Neptunea stilesi* could be considered to be an off-shoot from *N. beringiana* stock that has developed in a new, more southerly region under changed ecological conditions but this can hardly be more than pure speculation.

ACKNOWLEDGMENTS

Thanks are due to the following associates in the California Academy of Sciences: Mr. Dustin D. Chivers for his excellent microscope slide preparations of radulae; Dr. Victor Zullo for photographing the radula slide used on Plate 14; and to Mr. Maurice Giles for photographing the shells and the preparation of the black-and-white prints used for illustrations.

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An Investigation of the Commensals of *Cryptochiton stelleri* (MIDDENDORFF, 1846) in the Monterey Peninsula Area, California

BY

STEVEN K. WEBSTER

Department of Biological Sciences, Stanford University, Stanford, California 94305

(5 Text figures)

INTRODUCTION

THE GIANT CHITON OF THE Pacific Coast, *Cryptochiton stelleri* (MIDDENDORFF, 1847), occasionally attains a length of 35 cm, and often harbors commensals in its pallial grooves. A pea crab, *Opisthopus transversus* (RATHBUN, 1893), and a polynoid worm, *Arctonoe vittata* (GRUBE, 1855), are frequently found in the pallial grooves of *C. stelleri* in the Monterey Peninsula area. These grooves, each with a row of about 70 ctenidia, are bordered on the inside by the dorso-lateral edges of the foot and on the outside by the girdle margins.

While *Arctonoe vittata* may be found free-living under rocks, *Opisthopus transversus* is always found as a commensal. Both *O. transversus* and *A. vittata* some of these are *Solaster*, *Dermasterias*, *Pisaster*, *Henricia*, *Crossaster* (asteroids); *Stichopus* (a holothurian); *Diodora*, *Acmaea*, and *Puncturella* (gastropods). *Opisthopus transversus* is also found with *Megathura*, *Aplysia*, and *Astraea* (gastropods); *Mytilus*, *Tresus*, and the siphons of pholads (pelecypods); and *Stichopus* (HARTMAN & REISH, 1950; DAVENPORT, 1950; RICKETTS & CALVIN, 1962; BEONDÉ, 1968). A more complete list of hosts for *O. transversus* can be obtained in BEONDÉ (1968).

The primary objective of this investigation was to determine the incidence and distribution of the commensals on *Cryptochiton* in the Monterey Peninsula area. In addition, observations were made concerning the natural history of *Cryptochiton*, and experiments on the role of diffusible attractants to commensals produced by *Cryptochiton* were conducted.

FIELD METHODS

Two subtidal sites were chosen within which dives were made using SCUBA equipment. The two stations were: Cabrillo Point, Monterey Bay (121°54'10" W; 36°37'30" N) and San Jose Beach (121°55'30" W; 36°30'50" N) on more exposed coast 2 miles S of Carmel. Both sites contained granite boulders surrounded by granite gravel and shell fragments. Boulders extended to a depth of 20 m at Cabrillo Point and to over 50 m at San Jose Beach. These sites were chosen for their accessibility and because they represented contrasting conditions of exposure. While the largest number of dives was made between October, 1966 and September, 1967 (20 at each site), several dives were conducted in June and July, 1965. The data from both periods have been included in the discussion. A single dive was made in August, 1965, on the shale beds ¼ mile offshore at Del Monte Beach, Monterey Bay.

Dives were of about 45 minutes' duration and involved the use of either rectangular or zig-zag swimming patterns in order to avoid repeated encounters with the same chitons. Each chiton was removed from the substrate and turned over to expose the pallial groove. When the chiton began to curl and close the pallial grooves, a finger was inserted in the anterior end of the groove and moved posteriorly, exposing the groove and commensals. Specimens which curled so tightly as to preclude thorough examination were not counted. Notes on the numbers of *Cryptochiton* and commensals observed were recorded on an underwater slate. The incidence of juvenile *Arctonoe* (less than 3 cm) was recorded separately. Additional obser-

ventions (physical conditions, behavior, etc.) were recorded shortly after each dive.

RESULTS OF FIELD WORK

Although chitons were observed most frequently on granite boulders, they were occasionally seen on gravel within a meter or so of large boulders. In addition, *Cryptochiton* was found in both stations on *Diapatra ornata* (MOORE, 1911), a polychaete tube-worm, apparently to browse on red algae found in association with the worm colonies. *Cryptochiton stelleri* in both sites was distributed more or less uniformly at depths of about 4 to 40 m. An occasional aggregation of 3 or 4 specimens was observed.

Most of the chitons were between 20 and 35 cm long. Young specimens of 12 to 20 cm were common in some areas. Smaller individuals were rare but are more common intertidally. *Cryptochitons* were observed browsing red and brown algae common to these rocky subtidal areas. *Gigartina*, *Iridaea*, small *Laminaria*, *Ulva*, and *Macrocystis* are common foods (TUCKER & GIESE, 1962). I also found them feeding on *Plocamium* and various coralline red algae. Although RICKETTS & CALVIN (1962) mention that feeding occurs primarily at night intertidally, numerous individuals were observed in both subtidal stations feeding actively during daylight hours.

1) Incidence of Commensals on *Cryptochiton* (Figures 1 to 4)

While *Arctonoe* occurred on *Cryptochiton* at both San Jose Beach and Cabrillo Point, *Opisthopus* was found only at Cabrillo Point and on the shale beds opposite Del

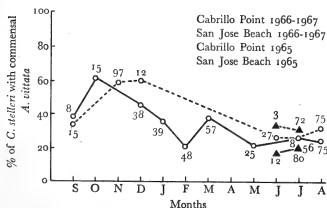


Figure 1

Numbers adjacent to points on the graph represent the numbers of observations from which the % of incidence of commensals on *Cryptochiton* was calculated.

Monte Beach. It appears, therefore, that *Opisthopus* is confined to Monterey Bay.

The incidence of *Arctonoe* (Figure 1) reached a maximum of nearly 60% at both stations between October and December. The minimum incidence of 22 to 25% occurred in both stations between May and August. Juvenile *Arctonoe* were most abundant in August and September (Figure 2), just preceding the period of highest adult incidence. These data indicate that a high yearly turnover rate may be occurring within the *Arctonoe* population.

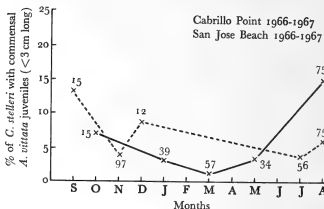


Figure 2

Numbers adjacent to points on the graph represent the numbers of observations from which the % of incidence of commensals on *Cryptochiton* was calculated.

The incidence of *Opisthopus* (Figure 3) fluctuated somewhat throughout the year but was considerably more stable than that of *Arctonoe*. The incidence of *Opisthopus* at the Cabrillo Point station averaged between 20 and 40% throughout the year. The incidence of *Opisthopus* in the shale beds during August, however, was 90%. The occurrence of more than one commensal *Opisthopus* on a single chiton was common in this area. Two chitons harbored 2 *Opisthopus* each (both in the same pallial groove), and one chiton contained 3 (2 in one groove, one in the other). The high incidence of *Opisthopus* might be a result of the abundance of rock-boring clams (*Pholadidae*), whose siphons may provide space for large numbers of *Opisthopus*. Encounters between *Opisthopus* and potential host chitons seem more likely in this area than at Cabrillo Point where potential *Opisthopus* hosts are less dense.

While *Cryptochiton* was often found to harbor 2 or even 3 *Opisthopus* at one time, chitons were never found to harbor more than one *Arctonoe*. Several *Cryptochitons* observed at Cabrillo Point contained both *Arctonoe* and

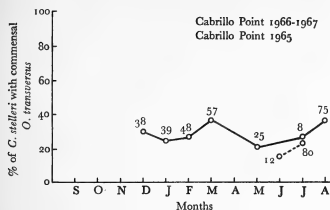


Figure 3

Numbers adjacent to points on the graph represent the numbers of observations from which the % of incidence of commensals on *Cryptochiton* was calculated.

Opisthopus, one of each in opposite pallial grooves. These combinations were most abundant (18½% incidence) in December, coinciding with the period of maximum occurrence of *Arctonoe*. The incidence of *Opisthopus* alone is average (31.6%) during December. This appears to be one of the few instances where more than one species of commensal is found at the same time on one host.

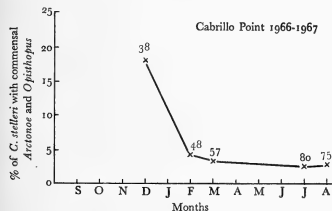


Figure 4

Numbers adjacent to points on the graph represent the numbers of observations from which the % of incidence of commensals on *Cryptochiton* was calculated.

2) Position and Orientation of Commensals

Arctonoe were usually found wholly within and toward the anterior end of the pallial groove, facing anteriorly.

The worms were usually clinging to the dorso-lateral surface of the grooves or to the ventral surfaces of the ctenidia. In either case, the worm is upside-down in relation to the *Cryptochiton* and the substrate. Occasionally, *Arctonoe* was found clinging to the ventral surface of the foot of *Cryptochiton*, or partially within the groove and partially on the foot. In such cases the worm also faces anteriorly and is upside-down.

Opisthopus was always found within the pallial groove, any place throughout its length; they were either upside-down or right-side-up, but always faced the midline of the host.

The crabs were often found to have varying amounts of mucus adhering to them, which presumably originates from the pallial mucous tracts on the inner walls of the pallial grooves. Mucus was rarely found adhering to *Arctonoe*.

DISCUSSION

By labeling the relationships between *Arctonoe*, *Opisthopus* and *Cryptochiton* as commensal ones, it is assumed that the commensals derive some benefit from the host at its expense, without harming it. It is evident that the pallial grooves of the *Cryptochiton* provide shelter for the commensals that is well protected from wave surge, predators, and desiccation (during rare periods of intertidal exposure). The respiratory currents in the pallial grooves also provide the commensal with a nearly continuous supply of sea water containing plankton and bits of detritus, a ready supply of food. Gut analyses of *Arctonoe* indicated that they are detritus feeders. That they always face the inhalant stream and are never observed crawling on the substrate would seem to support this interpretation. The frequently observed association of *Opisthopus* with the pallial mucus might indicate that the mucus and its contents serve as food for the crab.

Both *Arctonoe* and *Opisthopus* produce planktonic larvae. It is possible that the initial contact of these commensals with *Cryptochiton* occurs when they are in the plankton and that they are carried into the pallial grooves via the inhalant respiratory current. Settling and metamorphosis might then occur within the pallial grooves. It is also possible that both commensals enter the *Cryptochiton* as metamorphosed juveniles or as adults. An undisturbed *Cryptochiton* lifts the margin of the girdle both anteriorly and posteriorly to form the inhalant and exhalant openings to the pallial grooves. These raised portions of the girdle would provide easy access for commensals. The smallest of the commensal organisms observed in *Cryptochiton* were already adults. Additional study of this question is warranted.

LABORATORY STUDIES

Introduction and Methods

The presence of substances which serve as physiological attractants of the host for its commensals has been demonstrated by DAVENPORT (1950) and DAVENPORT & HICKOCK (1951) in the *Arctonoe fragilis* - *Evasterias* association. Using an apparatus similar to the one used by these authors, the *Arctonoe vittata* - *Cryptochiton stelleri* relationship was investigated for the presence or absence of such an attractant. A Y-shaped tube was constructed of 1/16 inch plexiglass, with inside dimensions of $2\frac{1}{2}$ by $2\frac{1}{2}$ cm. The stem was 20 cm long and the two arms were 10 cm each. Each arm of the Y-tube was connected to two plywood tanks each with a volume of one cubic foot. Pinchcocks were installed to control the flow of water from the tanks to each arm of the Y-tube such that water could be directed from either tank to either arm of the tube (Figure 5). Each tank contained sea

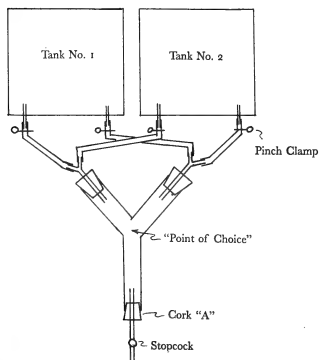


Figure 5

water with a temperature between 15.8 and 17.0° C. Sea water was added to maintain the two tanks at equal levels. Between trials, sea water was run through all tubing. The flow characteristics of the Y-tube were

checked with dye, indicating that a definite side-to-side concentration gradient occurred at the "point of choice" where water from each arm of the Y-tube converged.

A *Cryptochiton* without commensals was placed in one tank of sea water, while the second tank contained sea water only. The appropriate pinchcocks were opened to allow for flow from the two tanks into opposite arms of the Y-tube. When the stem of the Y-tube was filled, cork "A" was removed and a commensal inserted. The cork was then replaced. The speed of flow was adjusted so as not to wash the commensal backward. Flow of water through the arms of the Y-tube was alternated from one trial to the next.

If after 10 minutes the commensal failed to enter either arm of the Y-tube, a failure was recorded but not counted. Entrance of the commensal into the plain sea water arm was counted as "negative." Movement into the arm containing water from the tank with the *Cryptochiton* was considered "positive."

RESULTS

	<i>Arctonoe</i>	<i>Opisthopus</i>
Number of trials	45	45
Number of failures	5	1
Number and % of movements into the <i>Cryptochiton</i> arm	34 (85%)	33 (75%)
Number and % of movements into sea water arm	6 (15%)	11 (25%)
P	>0.01	0.05 to 0.01

DISCUSSION

Two other experiments were performed, for which data are not presented in detail.

Both *Opisthopus transversus* and *Arctonoe vittata*, or *A. vittata* - *A. pulchra* (JOHNSON, 1897) "intergrades" inhabit the cloacal chamber of *Stichopus californicus* (STIMPSON, 1857), a holothurian common in both stations (DAVENPORT, 1950). An experiment was run in which *Stichopus* (free of commensals) was substituted for the *Cryptochiton* and tests made on *Arctonoe* and *Opisthopus* collected from the pallial grooves of *Cryptochiton*. In 31 trials, a considerably larger number of "failures" occurred with *Stichopus* than with *Cryptochiton* in the previous experiment, and the runs into the two arms of the Y-tube approached randomness.

An experiment was conducted with *Stichopus californicus* in one tank and *Cryptochiton stelleri* in the other. *Arctonoe vittata* and *Opisthopus transversus* collected from *Cryptochiton* were tested. Thirty trials were made with each commensal. The results were essentially identical with those of the first experiment, with both commensals showing a preference for the arm containing water from the tank with *Cryptochiton*.

Although the above data are based on too few trials to be conclusive, I believe the presence of a diffusible chemical serving as an attractant produced by *Cryptochiton stelleri* is indicated. It seems possible that *Stichopus* produces a diffusible attractant which operates as such only on commensals previously conditioned to it in their development. Such an adaptation might be entirely independent of genetic factors (DAVENPORT, 1950).

ACKNOWLEDGMENTS

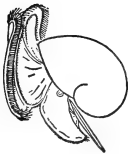
The author wishes to express his appreciation to Dr. Donald P. Abbott, Dr. Myra Keen, and Eugene V. Coan for their helpful suggestions in the preparation of the manuscript.

The services of George W. Ackerman and Don G.

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Notes on the Habitat and Anatomy of *Jouannetia quillingsi* from North Carolina Coastal Waters

BY

DOUGLAS A. WOLFE

Bureau of Commercial Fisheries, Radiobiological Laboratory
Beaufort, North Carolina 28516

(Plate 15; 1 Textfigure)

Jouannetia quillingsi IS A RARE BIVALVE which I have recently discovered burrowed into pieces of marl and sandstone submerged in coastal waters near Beaufort, North Carolina. Before describing *Jouannetia* (*Pholadopsis*) *quillingsi* (Pholadidae; Jouannetiinae) as a new species, TURNER (1955) examined (among others) 2 specimens collected in 1885 on the *Albatross* cruises southeast of Cape Fear, North Carolina. The specimens came from depths of 17 and 18 fathoms, but no records were available on whether the specimens were living or dead, or on the substratum in which they were found. Specimens of *J. quillingsi* are rare, and the species has not been reported from elsewhere off North Carolina, even though several faunal surveys have been conducted in the area (CERAME-VIVAS & GRAY, 1966; MENZIES *et al.*, 1966; WELLS, WELLS, & GRAY, 1964; PEARSE & WILLIAMS, 1951). The soft parts of this species were heretofore unknown.

Throughout 1966 and in early 1967, several boats from Beaufort, North Carolina, regularly trawled for calico scallops in 10 to 15 fathoms just south of Beaufort Inlet and west of Cape Lookout (approximately 34°20'-32' N; 76°35'-55' W). The bottom in this area consists mainly of sand and shell fragments, but large pieces of Trent marl, coquina and coral (*Siderastrea elegans*) were encountered occasionally in the trawls. I periodically met the trawlers at the dock to collect specimens from the catch as it was unloaded. On January 23, 1967, I found several large pieces of Trent marl which had been dumped beside the dock after the previous day's work. Nine dead, but otherwise intact, specimens of *Jouannetia quillingsi* were retrieved from their tight burrows in one piece (about 10 in. x 7 in. x 2½ in.); 2 others in the same rock were discarded because they were badly damaged. No more specimens were found in other similar pieces of rock in the same pile. The clams had been out of the water at least 27 hours, but no more than 36 hours; the tissues were

still quite moist, but were probably in early stages of decomposition. Seven of the 9 specimens were preserved in 40% methanol containing 0.1 molar Na₂CO₃; the others were cleaned and dried, one *in situ* in its burrow (No. 1253; Plate 15, Figure 1 a). Other specimens (about 20 in all) were collected from burrows in similar rocks trawled from the same area on January 17, March 2, March 3, and May 12, 1967 (No. 1544; Plate 15, Figure 1 b), but only one of these (No. 1366; March 2, 1967) contained the soft parts; it was preserved as described above. Several small immature specimens were also included in the March 2 sample. A representative selection of immature and adult specimens, including the one illustrated in Plate 15, Figure 1 b, now is in the collection at the Museum of Comparative Zoology, Harvard University.

HABITAT AND ECOLOGY

Substratum: All specimens of *Jouannetia quillingsi* were burrowed into the tops or sides of pieces of soft rock obtained from depths of 10 to 15 fathoms. The rock usually was marl (limestone) from the Trent Formation, which outcrops at several points along the continental margin of the Carolinas (PEARSE & WILLIAMS, 1951). In one such piece of marl, recent burrows and shells of *J. quillingsi* were found among a concentration of lower Miocene fossil casts of *Venus gardneri* KELLUM. On March 3, 1967, *J. quillingsi* were found in a softer piece of rock (Plate 15, Figure 2), which seemingly consisted of cemented sand grains, more nearly characteristic of the formations of coquina in this area (WELLS & RICHARDS, 1962; MENZIES *et al.*, 1966). The shell of *J. quillingsi* completely fills the lower part of the burrow, and the callum of the left valve in the adult is loosely cemented against the bottom and sides of the burrow so that

only the right valve is free to move (Plate 15, Figure 1). The callum, which is so extensive in the non-burrowing adult, is completely lacking in young burrowing specimens. *Jouannetia*, like other callum-building pholads (TURNER, 1954), probably extends its foot through the anterior gap of the shell while burrowing, but when burrowing ceases, the callum is built and the foot is

resorbed. The siphons must be extended a few millimeters behind the siphonoplax to reach the narrow (2 to 4 mm diameter) aperture of the burrow (Plate 15, Figure 2). The entrances to the burrows are extremely inconspicuous from the outside; the posterior end of the siphonoplax of the entrenched mollusk is generally not visible through the aperture. *Jouannetia quillingi*'s apparent preference

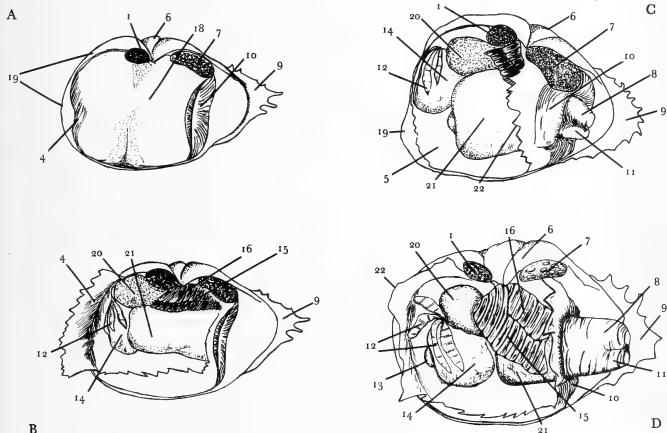


Figure 1

Internal morphology of *Jouannetia quillingi*

A: Specimen collected January 23, 1967, with left valve removed.
B: Same specimen, with left mantle laid back. C: Different

specimen from same sample, left mantle laid back. D: Specimen collected March 2, left mantle laid back.

Explanations of numbers (after TURNER, 1962)

1. Anterior adductor muscle
4. Thickened anterior margin of mantle
5. Mantle
6. Shell
7. Posterior adductor muscle
8. Excurrent siphon
9. Siphonoplax
10. Siphonal retractor muscle
11. Incurrent siphon
12. Labial palps
13. Foot
14. Visceral mass (abdominal mass of FISCHER, 1860, 1862)
15. Inner demibranch of gill
16. Outer demibranch of gill
18. Closed mantle of adult
19. Edge of calcareous callum
20. Brownish digestive tissue
21. Retracted siphons
22. Cut edge of mantle

for substrata of soft rock is characteristic of other species of the genus, although the holotype of *J. quillingsi* was reportedly found in submerged and rotted wood (TURNER, 1955).

Associated Mollusks: Principal mollusks found in conjunction with *Jouannetia quillingsi* on and in similar pieces of rock taken in hauls made for calico scallops are listed below:

GASTROPODA

Vermicularia spirata PHILIPPI, 1836

Vermicularia knorri (DESHAYES, 1843)

PELECYPODA

Lithophaga bisulcata (ORBIGNY, 1842)

Lithophaga aristata (DILLVYN, 1817)

Gastrochaena hians GMELIN, 1791

Gastrochaena ovata SOWERBY, 1834

Petricola typica (JONAS, 1844)

Hiatella arctica (LINNAEUS, 1767)

Pododesmus rudis (BRODERIP, 1834)

Diplodonta punctata (SAY, 1822)

Chama macerophylla GMELIN, 1791

Chama congregata CONRAD, 1833

Pseudochama radians (LAMARCK, 1819)

Arca imbricata BRUGUIÈRE, 1789

ANATOMY OF *Jouannetia quillingsi*

Three preserved specimens were dissected: two from the January sample and the one collected on March 2. The tissues of the former specimens were very soft and disintegrated upon extensive probing, and the tissues in the latter were distinguished much more readily. General internal morphology of all 3 specimens is shown in Text figure 1. For convenience, the numbers identifying anatomical features are the same, where possible, as those used by TURNER (1962).

Upon removing the left valve with its overlapping callum, one sees only the adductor muscles and the closed mantle of the organism (Text figure 1 A). The mantle is thickened along the anterior margin and also posteriorly where it joins the siphonal retractor muscles. In the 3

specimens dissected, the siphons were fixed in different positions, ranging from fully extended (Text figure 1 D) to completely retracted (Text figure 1 B). The siphons are of equal length and are covered with a rather heavy brown periostracal sheath.

When the mantle is opened and laid aside (Text figures 1 A to 1 D), the most prominent anatomical feature is the large, white, smooth, rounded body of the retracted siphons (No. 21). When the siphons are fully retracted (Text figure 1 A, 1 B), they occupy most of the space enclosed by the mantle and thereby displace the visceral mass anteriorly and dorsally. The visceral mass is differentiated into a cream-colored ventral portion (No. 14) and a more dorsal brownish digestive gland which was greenish in the March 2 specimen (No. 20). The paired labial palps are long and strap-like and lie on either side of the slit-like mouth on the antero-dorsal surface of the cream-colored portion of the visceral mass. The labial palps were overlooked during the dissection of the first 2 specimens because of the condition of the tissues, but I have included them in their proper position in Text figures 1 B and 1 C. The 2 paired demibranchs of the gill are situated mainly dorsal and posterior to the visceral mass and the retracted siphons.

The anatomy of *Jouannetia quillingsi* differs somewhat from that of *J. cumingi* and *J. globulosa* as illustrated by FISCHER, 1860, 1862. [FISCHER's original drawings are reproduced in part by TURNER, 1962.] FISCHER pictures the siphons of both *J. cumingi* and *J. globulosa* as being very much shorter than those of *J. quillingsi*, so that the mantle cavity is occupied by only the visceral mass, labial palps, and gills. FISCHER also does not mention any differentiation of the visceral mass, a feature quite noticeable in my 3 dissections of *J. quillingsi*. According to TURNER (1954, 1962), a detailed description of the anatomy of *J. cumingi* SOWERBY is given also in a private publication by EGGER (1887), but I have been unable to examine this reference.

SUMMARY

Jouannetia quillingsi TURNER, 1955, first found off the coast of North Carolina during the *Albatross* cruises of

Explanation of Plate 15

Jouannetia quillingsi from 10 to 15 fathoms off Beaufort, North Carolina

Figure 1 a: Dorsal view of specimen *in situ* in shallow burrow in Trent marl. The original entrance of the burrow was destroyed during removal of excess rock.

Figure 1 b: View of left valve of deeply embedded specimen. The

upper one-half of the burrow has been removed.

Figure 2: Typical burrow of *Jouannetia quillingsi* in soft cemented sandstone, sectioned to show the shape and proportions of the burrow.



Figure 1 a

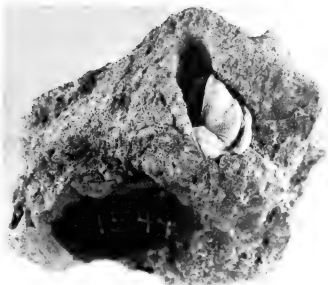


Figure 1 b



Figure 2

1885, has been rediscovered south of Beaufort Inlet in 10 to 15 fathoms. The species lives burrowed into soft marl and sandstone. It seems likely that the rarity ascribed to the species arises at least partly from the seclusion afforded by its inconspicuous burrows in submerged rock. The general internal morphology of the species, heretofore unknown, has been described.

ACKNOWLEDGMENTS

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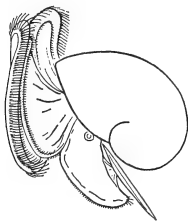
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Some Observations on the Ecology and Behavior of *Lucapinella callomarginata*

BY

RICHARD L. MILLER

Department of Zoology, Oregon State University, Corvallis, Oregon 97331
and the Kerckhoff Marine Laboratory, Corona del Mar, California 92625¹

(Plate 16; 1 Text figure)

INTRODUCTION

McLEAN (1967) IN HIS REVISION OF THE West American species of *Lucapinella* reported *Lucapinella callomarginata* (DALL, 1871) from the intertidal: "on the underside of rocks and on pilings near aggregations of *Mytilus edulis* in bays and channels in southern California. It has not been collected in the sub-littoral zone." No report other than this exists as to the habitat of this species, nor is there any description of the general biology of this organism. During the late summer of 1967, while dredging in the main channel leading to upper Newport Bay, California, I found 2 *L. callomarginata* in a radically different niche - the mud-flat sponge *Tetilla mutabilis* DE LAUBENFELS, 1930. Subsequent collections and laboratory observations have served to confirm and extend this finding.

COLLECTIONS AND PRELIMINARY OBSERVATIONS

Dredging runs, made parallel to the northern shore of the channel about 300 yards east of the Route 101 bridge in about 10 to 15 feet of water, yielded a large number of *Tetilla* and 2 limpets were found tightly embedded in one of them. The importance of this find was not realized at the time, so no further search was made for limpets. The 2 limpets were brought back to the laboratory for identification and kept isolated in a running sea-water aquarium for 2 weeks before a fresh sponge was provided. The animals moved under the sponge and burrowed up and into it.

A second collection was made some weeks later at the same location by raking sponges by hand and a total of 9 limpets was recovered from 15 sponges. In most cases, if one limpet was found in a sponge, others would be present. Three limpets were placed on one of the sponges brought back to the laboratory at this time and it was used for the photographs in Plate 16.

A third collection was made at a small marina just east of the bridge, where, at low tide, sponges could be raked by hand in from 3 to 5 feet of water. Both *Tetilla* and a massive, branched, yellow sponge (tentatively identified as a species of *Halichondria*) were found, but there were only 3 limpets in about 30 specimens of *Tetilla*. All of these were found in one sponge. This particular *Tetilla* was highly irregular in form with 4 large oscula, whereas the vast majority of the others was more regular, with a single central osculum (Plate 16, Figure 5). The *Halichondria* (?) contained no limpets.

A fourth collection was made from the pilings under the bridge in an attempt to recover animals in the habitat described by McLEAN. A single limpet was found here away from any sponge. This animal was brought back to the laboratory alive for analysis of the contents of the fecal pellets.

EXTERNAL MORPHOLOGY OF *Lucapinella callomarginata*

Figures 1 to 4, Plate 16, are photographs taken of a representative specimen of *Lucapinella callomarginata*. Figure 1 is a dorsal view, showing the highly sculptured shell, the fringed mantle, the excurrent siphon set off by an anterior and posterior set of 6 or more large, fleshy papillae, and the massive posterior portion of the foot. Figure 2 shows the same animal from the side. The ante-

¹ Current address: Department of Biology, Temple University, Philadelphia, Pennsylvania 19122

rior end is to the right in the figure. The fringed mantle extends just over the edge of the shell and down over the foot for a distance of 2 to 4 mm. The portion of the mantle shielding the head is considerably broader than the portion that extends over the foot. Each of the mantle papillae on the upper portion of the flap appears to line up with a shell ridge. Many times two anterior portions of the mantle are held up, forming fan-shaped openings on either side of the head at about the position of the tentacles. This can be seen from above in the upper lefthand animal in Figure 4, Plate 16 and is probably used as a method of increasing the incurrent water flow. The excurrent siphon is extendable to at least 5 mm above the shell surface at the aperture. An animal with its siphon extended is shown in Plate 16, Figure 6. The shell of this animal has been described (McLEAN, 1967).

Figure 3, Plate 16, shows an animal resting in the lower corner of an aquarium. The lower mantle flap has been lifted, displaying the proboscis, head tentacle, and a line of epipodial tentacles decreasing in size posteriorly. The obvious fold in the foot is not a permanent structure. Figure 4, Plate 16, shows 6 animals found during one of the collecting trips and demonstrates the variability in shell and body color and the differences in spot patterns on the surface of the foot. In general, the over-all color of the flesh is an orange-brown to orange-red. The larger scattered spots on the foot range from darker shades of brown to black. The brown or reddish color tended to fade when the animals were kept away from sponges.

FEEDING BEHAVIOR

General observations were made of the feeding behavior of *Lucapinella callomarginata*. The animals appear to attack *Tetilla* anywhere along the sides but seem to prefer the area around the base where the sponge is attached to the mud (Plate 16, Figure 6). The limpet grazes on the surface and forms a cavity which is eventually enlarged to encompass the entire foot of the animal (Plate 16, Figure 8). The limpet crawls forward, burying itself in the sponge, evidently eating its way through. It may be covered by subsequent growth of the sponge around and over it (Plate 16, Figures 5, 6). As the limpet moves forward in the sponge, it creates a groove, one of which was 4 inches long. In 2 cases, limpets were seen to enter the sponge by way of the large osculum and commence feeding while in it. No experiments were done to see if the limpets were attracted to the sponge.

The fecal pellets of limpets grazing on *Tetilla* were collected and examined. They contained sponge spicules and unidentifiable debris. Several of the animals were then starved for a few days and presented a number of sponges

in isolation to determine if *Tetilla* was the sole food. In each situation fecal pellets were collected and a search was made for sponge spicules. The types found in the feces were compared with the spicules obtained from the sponge on which the animal was feeding. Text figure 1 summarizes the results when limpets were exposed to the sponges *Tetilla mutabilis*, *Hymeniacidon synapium* DE LAUBENFELS, 1930 (Plate 16, Figure 10) and the specimen of *Halichondria* (?) (Plate 16, Figure 9) mentioned earlier. As the figure shows, the limpets attacked all 3 sponges, and in each case the spicules in the feces, though somewhat broken up, matched those of the sponge endosome. Also shown (G) are the spicules found in the fecal pellets of the one limpet taken from the pilings. This assemblage, not found in any of the 3 sponges tested, is probably a conglomerate. The tylostyle is probably from a sponge in the family Clionidae while the prodiancane may be from the ectosome of *Tetilla* (DE LAUBENFELS, 1932). Indications are, then, that sponges of the order Demospongia are eaten and the limpets do not restrict their diet to a single genus. It is also evident that the limpets can do severe damage to the sponges they attack (Plate 16, Figure 9).

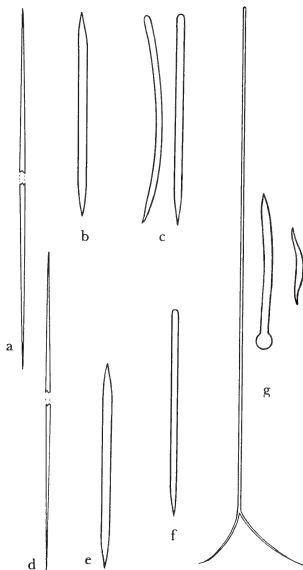
Since the limpets are often found in areas away from sponges (MacGinitie, personal communication), it is possible that these animals are grazers as well as predators. During a series of observations of isolated limpets it was noticed that portions of the surfaces of the aquarium had been cleaned of the coating of debris. Eventually, one limpet was observed through the glass wall of an aquarium to be grazing on the surface. In contrast to *Tegula* or *Haliotis*, the stroke of the radula was very short, which might be an indication that it is designed more for tearing than for scraping. Confirming evidence of feeding on algae was obtained from the feces of the limpet found on the bridge piling. Fragments of plant material were seen along with the spicules. No diatom tests were noted, though there was much unidentifiable debris present.

Although the animals may remain in one *Tetilla* for a considerable period of time, they must eventually exhaust the resources of their prey and have to find another sponge. Therefore, observations were made on the behavior of limpets placed on a soft, sandy-mud substrate. Surprisingly, the animals had little difficulty, making almost as rapid progress as they do on glass.

Initially, the anterior portion of the foot is splayed out in front of the animal, forcing itself into the mud. At the same time, the proboscis is extended forward as a narrow tube, sliding on the upper surface of the foot. When it reaches its maximum extension, the tip expands and remains expanded as the proboscis is drawn back

Figure 1
(← adjacent column)

(not to scale)



A. Tornote from the endosome of *Tetilla mutabilis*. The longest spicule seen measured about 33 mm in length while the smallest measured 8 mm.

B. Oxea from the endosome of the yellow sponge thought to be *Halichondria*. The largest measured 3.2 mm in length, 0.8 mm in width.

C. Style from the endosome of *Hymeniacidon synapium* (2 views). The largest measured 0.75 mm in length, 165 μ in width.

D. Tornote from the fecal pellets of a specimen of *Lucapinella callomarginata* fed only on *Tetilla mutabilis*. This was the only type of spicule found.

E. Oxea from the fecal pellets of a specimen of *Lucapinella callomarginata* fed only on *Halichondria* (?). This was the only type of spicule found.

F. Style from the fecal pellets of a specimen of *Lucapinella callomarginata* fed only on *Hymeniacidon synapium*. This was the only type of spicule found.

G. Representative assemblage of spicules found in the fecal pellets of a specimen of *Lucapinella callomarginata* collected on a piling in Newport Bay, California. Shown are (from left to right) a prodiaene, a tylostyle (0.15 mm length \times 40 μ width) and an oxea (100 μ length \times 5 μ width).

toward the head. The animal then glides forward. Posteriorly, the foot is spread out to at least twice the length of those shown in Plate 16, Figure 4, and the active secretion of mucus is in evidence as a trail of compacted mud behind the animal. In this manner, the limpet actively burrows along, though it was not seen to move into the mud above the level of the shell. The mantle flap is maximally lifted in the head tentacle areas and these openings may be pressed posteriorly or even obliterated by the mud piling up in front of and beside the animal. The epipodial tentacles are maximally extended. Small masses of sediment particles taken into the mantle cavity are ejected periodically through the excurrent siphon, which is also maximally extended.

Explanation of Plate 16

Figure 1: A specimen of *Lucapinella callomarginata* from above. The smallest scale division is 1 mm.

Figure 2: The same animal in side view. Same scale as Figure 1.

Figure 3: The same animal from below. The scale is in millimeters.

Figure 4: Six specimens of *Lucapinella callomarginata*.

Figure 5: A large specimen of *Tetilla mutabilis* in the "regular massive" form. The dish on which the sponge rests measures six inches in diameter. The arrow points to the position of a limpet. Two more limpets are in the sponge but hidden from view. Scale equals 25 mm (Figures 6 to 10 on same scale).

Figure 6: The same sponge in side view. The long root attachment system is clearly shown. The arrow indicates the position of the

limpet. The shell aperture and siphon of the animal are visible.

Figure 7: The same view with sponge overgrowth cleared away.

Figure 8: The limpet has been pulled out of the sponge. The large cavity left by the foot can be seen, as well as a thin layer of sponge still attached to the foot (arrow). The extended tentacles of the limpet can also be made out.

Figure 9: The same sponge after three weeks. Four possible centers of regeneration have been created. The two finger-like structures in the foreground are portions of the yellow sponge thought to be a species of *Halichondria*.

Figure 10: A large specimen of *Hymeniacidon synapium* collected in four feet of water at low tide.

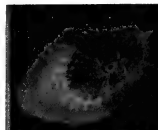


Figure 1

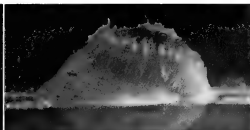


Figure 2

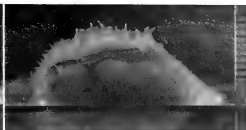


Figure 3

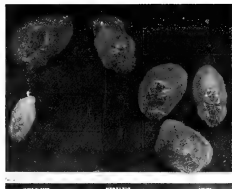


Figure 4

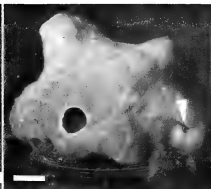


Figure 5

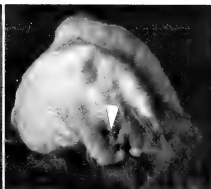


Figure 6

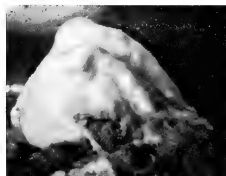


Figure 7

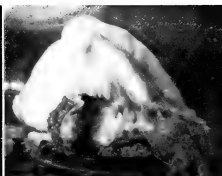


Figure 8



Figure 9



Figure 10

Some observations were also made of the behavior of the animals during spawning. Recently collected animals often spawned within 3 hours after being brought into the laboratory. Some of the animals which had been in the laboratory for a few weeks could be induced to spawn by placing them in a six-inch finger bowl. Evidently the rise in water temperature would trigger spawning. In one case, a number of animals was observed to spawn *en masse* in a 5-gallon capacity aquarium containing a healthy *Tetilla* on which they had been feeding. All of the animals appeared on the surface of the sponge close to the osculum prior to spawning. Each animal showed a definite contraction of the foot and uniform compression of the shell down against the foot every 3 to 5 minutes. This was accompanied by a burst of gametes from the excurrent siphon. Spawning lasted approximately 2 hours after which the limpets returned to the interior of the sponge. Some of the fertilized eggs were collected. They were encased in 2 jelly layers, an inner dense one about $100\ \mu$ thick, and an outer, less dense one, about $200\ \mu$ thick. The egg itself was a dull yellow color and $132\ \mu$ in diameter. Cleavage was not observed.

DISCUSSION

A number of interesting questions is raised by the finding that *Lucapinella callomarginata* feeds on the sponge *Tetilla*, as well as on other Demospongia. Since no observations were made on the detailed behavior of the limpets as they enter the sponges, the question remains as to the actual use of the foot during this process. It does provide a strong grip on the sponge, as attested to by the difficulty of pulling the limpets out of the sponges. In many cases, in fact, removal of the limpet would result in tearing away a layer of sponge that remained attached to the foot (Plate 16, Figure 8). Whether it could provide some leverage to aid the limpet in penetrating the sponge remains to be seen. The use of the foot and proboscis during locomotion in mud is interesting in this regard.

There is also the distinct possibility that the limpets rarely, if ever, completely destroy a sponge. Since natural growth rates may far exceed those in the laboratory the sponges in nature might well be growing faster than the limpets can eat them. Sponges are notorious for their sensitivity to laboratory conditions. Although *Tetilla* seemed to do reasonably well, there is always the possibility that some subtle deterioration was taking place that would make the sponges in the laboratory more susceptible to predation by the limpets and thus tend to amplify whatever effects the limpets might have in nature.

DE LAUBENFELS (1932) recorded two shapes for *Tetilla mutabilis*, "pedunculate-clavate" and "irregularly massive." In general, the "clavate" form has a relatively symmetrical shape with a central osculum and is rather small. The largest size observed by DE LAUBENFELS was 22 mm. This is probably the juvenile *Tetilla*. I have noticed that the "massive" form, on the other hand, commonly appears in two shapes, one "irregular" and the other "regular." The "irregular" has a low, almost flat outline and bears a number (3 or more, usually) of oscula, about 3 inches apart. This form is much larger than the "pedunculate clavate," and may be over 12 inches by 9 inches by 3-5 inches when full of water. The "regular massive" form resembles a much enlarged "clavate" form although its outline is more nearly spherical (Plate 16, Figures 5, 6). It bears a central osculum, from which extend, like blunt spokes, 3 or 4 irregular lobes of considerable thickness and it may be up to 6 inches or more in diameter. Limpets were rarely found in this form, and the one pictured in Plate 16, Figures 5, 6, 7, and 8 was introduced.

It is possible that the "irregular massive" form is produced from the "regular massive" by the predations of the limpets. Plate 16, Figure 9 shows the results of predation by 3 limpets on the "regular massive" sponge shown in Figure 5 after a period of 3 weeks. This collapsed form could easily give rise to the "irregular massive" form if the limpets left the sponge and regeneration occurred; the lobes of the "regular" form that remained giving rise to secondary centers of organization each with its own osculum.

Distribution of *Tetilla* is erratic in Newport Bay, although it is a common species. The few collections of limpets indicate that their distribution may be even more erratic. The largest number taken were in an area where great numbers of *Tetilla* occurred but too few collections were made in other areas to see if there was any correspondence. Locality records in the Los Angeles County Museum of Natural History collections reveal that large numbers of *Lucapinella* have been taken on the bridge pilings in the past, confirming a lack of restriction to sponges. I have noticed that *Tetilla* seems to disappear during the late spring or early summer and Dr. Charles Brokaw confirmed this (personal communication). Prof. G. E. MacGinitie stated (personal communication) that the sponge was seen during the months of October, January, February, and April. DE LAUBENFELS (1932) commented that although the sponges were extraordinarily plentiful in November, he could find none in June of that same year. Possibly there is a true seasonal bloom of *Tetilla* in Newport Bay, but it is doubtful that the distri-

bution of the limpet can be correlated with it, considering the prevalence of other edible sponges elsewhere in the bay.

Little is known of the feeding behavior of most Fissurellidae except the common assumption that the rocky intertidal reef-dwellers are surface grazers, foraging on the layers of diatoms and encrusting algae on hard surfaces. Dr. Jefferson Gonor has observed (personal communication), however, that the limpet *Diodora aspera* (ESCHSCHOLTZ, 1833) will seek out and consume encrusting bryozoans in preference to algae. FRETTER & GRAHAM (1962) report that *D. apertura* (MONTAGU, 1807) utilizes similar food sources. Sponges are common food sources of many opisthobranchs and some, such as *Rostanga pulchra* MacFARLAND, 1905 may have diets restricted to a single species (COOK, 1962). In some cases, the mollusks are definitely attracted by their food (COOK, *op. cit.*; LONG, 1967; OWEN, 1966). No tests were run to determine the attraction of *Lucapinella* to *Tetilla*. However, the possibility that the limpets do aggregate in a sponge once it is being attacked cannot be overlooked, since in most collections more than one limpet was usually found in a sponge. Observations on the feeding behavior of *Aeolidia* indicate that damaged prey becomes more attractive to other *Aeolidia* (STEHOUWER, 1952). In *Melongenina*, the first feeding organism rather than the prey becomes attractive to other *Melongenina*, which in turn attack the prey (TURNER, 1959). Attraction mechanisms like these are probably of advantage for spawning or mating purposes, and would certainly be of advantage to *Lucapinella*.

TURNER, RUTH DIXON

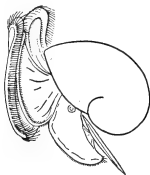
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Banding Patterns in *Haliotis* - IISome Behavioral Considerations and the Effect of Diet
on Shell Coloration for *Haliotis rufescens*, *Haliotis corrugata*,
Haliotis sorenseni, and *Haliotis assimilis*

BY

DAVID A. OLSEN

Zoology Department, University of Hawaii, Honolulu, Hawaii 96822¹

(Plate 17; 1 Table)

INTRODUCTION

IN A PREVIOUS PAPER (OLSEN, 1968) I attempted to develop a technique for using the sequence of colored bands in the shells of *Haliotis rufescens* SWAINSON, 1822 to trace the seasonal variation in the abundance of *Nereocystis luetkeana* (MERTENS) POSTELS & RUPRECHT, 1840, the primary component in the diet of the abalones in Morro Bay (Cox, 1962). *Nereocystis* is a large brown alga that floats well off the bottom. Commercial fishermen make it available to the abalones by cutting the stipes while diving and with the propellers of their boats. I mentioned that this technique could be used to study algal abundance in the abalone's home area and would also be of use to investigators interested in abalone growth rates. In addition, it would be useful in studying seasonal variations in feeding intensity as reported by INO (1943) and later tied in to seasonal temperature fluctuations by SAKAI (1962 a). Abalone growth rate is economically important since *Haliotis* is a widespread genus with some 50 or more species (SORENSEN, 1949) and is important in a number of countries including Japan, Australia, South Africa, Mexico, and the United States of America. FORSTER (1967) discusses the importance of growth rate data in fisheries investigations.

Before the information contained in the banding patterns can be used by sublittoral ecologists certain behav-

ioral information must be considered. The most important aspect to be considered is whether the animals graze the macroalgae in their immediate vicinity or trap food particles which are carried to them by currents and surge. Any attempt to use the banding patterns to study the algal abundance in the abalone's home area would certainly be unsuccessful if the animals were eating food that was carried to them by the current from a distant point.

Haliotis feeding behavior has been reported for a number of species. Cox (1962) says that the red abalone, *H. rufescens*, feeds by extending its epipodium and capturing pieces of macroalgae that float by in the drift. SINCLAIR (1963) described the grazing of *H. iris* kept in aquaria. She also described populations of abalones living in the New Zealand tidepools where there were no algae available for grazing. She hypothesized that the abalones left these pools at night in order to feed, but it seems possible that they feed by trapping algal debris washed into these pools.

STEPHENSON (1924) describes the grazing of captive *Haliotis tuberculata* LINNAEUS, 1758 in England, but also mentions inducing animals in nature to feed by holding a piece of *Fucus* near the mouth. From these and other studies it appears that although abalones will graze, the normal method of feeding is by capturing particles of macroalgae in the drift.

Cox (1962) reported annual growth of *Haliotis rufescens* of up to 48 mm but says that it is irregular and varies greatly. LEIGHTON & BOOLOOTIAN (1963) found the annual growth rate of *H. cracherodii* LEACH, 1817 to be 20 mm. In England, FORSTER (1967) found that *H. tuberculata* grew 15 to 16 mm per year. SAKAI (1962 b)

¹ This work was completed while the author was working on the Master of Arts program in the Department of Biological Sciences at the University of California at Santa Barbara. The computer analysis was supported by University of California Committee on Research grant for computer research no. 5997.

found that *H. discus hannai* Ino, 1953 grew an average of 20 mm per year over a 5-year period. Commercial fishermen report annual growth of up to 2 inches (51 mm) but feel that $\frac{1}{2}$ inch (13 mm) is more likely the average figure.

It is the purpose of this paper to supply the behavioral information that is necessary before this shell banding information can be used for dating purposes. In addition, I have presented the results of a series of feeding experiments which were an extension of the diet and shell color studies of Ino (1952), SAKAI (1962 a) and LEIGHTON (1961, 1963). A preliminary attempt at taking the yearly patterns of shell colors and utilizing them to group the sample into age classes is also reported.

MATERIALS AND METHODS

Growth was measured by taking the shell band data described in the previous paper and totalling the distance from one red winter band to (but not including) the next. This was done with a simple program on an IBM 360-50 computer.

To study the effects of changes in diet upon shell color, 5 species of abalones were collected by SCUBA divers, brought into the laboratory, placed in 8-liter plastic pans, and maintained at 14 to 20° C in running sea water. I used small individuals because of space limitations and because earlier workers reported a rapid early growth rate. The number of individuals, species, and the size range were as follows: 8 *Haliotis rufescens* (64 to 153 mm), 10 *H. sorenseni* BARTSCH, 1940 (64 to 127 mm), 4 *H. assimilis* DALL, 1878 (51 to 102 mm), 3 *H. corrugata* GRAY, 1828 (19 to 140 mm), and 1 *H. cracherodii* (33 mm). The animals were fed by placing a liberal quantity of the algae into the tank and leaving it there until it was eaten or until it began to deteriorate. The tanks were cleaned regularly to prevent growth of other species of algae which would contaminate the experiment. The animals were fed one species of algae until there was an obvious area of new shell growth. At this time they were transferred to another condition. They were fed *Macrocystis* as a brown alga, *Gelidium* for red and *Enteromorpha* for green alga.

Behavioral information came from the abalones used in the shell color studies, from a series of simple condi-

tioning experiments run predominantly on red abalones, and from 2 years spent as a commercial abalone fisherman. The behavioral observations were conducted in the following manner: after collection, the abalones were placed in tanks with running sea water; the tanks were 4 x 4 x 1 foot in dimension. The abalones were left alone for 3 or 4 days to acclimate themselves. The experiment itself consisted of touching the epipodial, cephalic, and respiratory tentacles with *Macrocystis*, probes, and in one series, juice from ground *Macrocystis*. Any change in the behavior of the animal was then recorded. Forty *Haliotis rufescens* were used in these experiments.

RESULTS

Annual Growth: There were 361 annual band series (from one red, or winter band, to but not including the next red band) observed in the 45 shells. This gives an average age of the animals used in this study of 8.02 years. There was too much variation in the width of the year bands to group them into well defined year classes. The width of these bands represents one year's growth and the average was 17.13 mm ($S^2 = 256$). The width of these annual bands ranged from 2 mm to 146 mm.

Shell Color and Diet: The results of the feeding - shell color study are listed below and in Table 1 by species. The colors given are comparable to colors listed in MAERZ & PAUL (1950); the designations in the atlas are given in parenthesis with each color.

Haliotis sorenseni: Red algae in the diet in every case resulted in a deep red color (L-7, p. 36) while brown algae resulted in green-white (G-9, p. 77) or brown-white (I-3, p. 47). The shell color of the Sorensen abalones that were fed green algae was the same green-white as when the animals were fed brown algae. None of the abalones formed blue-grey shell, a color frequently encountered in specimens collected from waters deeper than 15 m.

Haliotis rufescens: New shell growth was red (L-7, p. 36) on a red algal diet. When fed brown algae, animals with shells under 85 mm formed new shell of a pale blue-green color (E-4, p. 77), while the larger animals had shells of brown-white (A-1, p. 47).

Haliotis corrugata: New shell growth of *Haliotis corrugata* was a brown-red (J-12, p. 36) in every case when

Explanation of Plate 17

Figures a to c: Feeding behavior of *Haliotis cracherodii*.

a: Epipodial tentacles are extended into the water in search of food.
b: Contact is made with a piece of *Macrocystis* and the animal extends the foot to capture it. After the food is captured, it is pulled under the foot (c) before the animal commences eating.

Figure d: Defensive behavior of *Haliotis rufescens*.

The epipodial tentacles are extended while the shell is clamped down close to the substrate.

e - epipodial tentacle; f - foot; m - piece of *Macrocystis* frond; r - respiratory tentacle



Figure 1 a

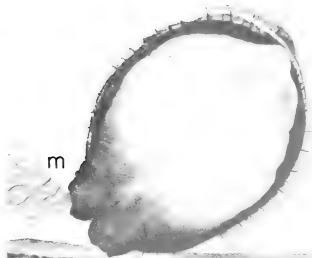


Figure 1 b

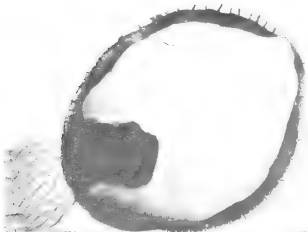


Figure 1 c

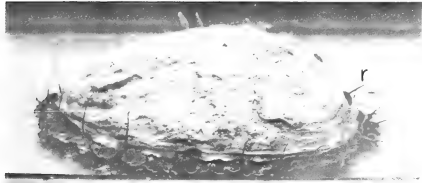


Figure 1 d

Table 1

Haliotis Shell Color Under Various Algal Diets

Species (sample size)	Red algae	Brown Algae	Green Algae	Diatoms
<i>Haliotis assimilis</i> (4)	red, blue, and white mottled	turquoise and white mottled pale brown orange		
<i>Haliotis corrugata</i> (3)	brown-red	turquoise, white		
<i>Haliotis cracherodii</i> (1)	reddish-brown ¹	blue-black blue-green ¹		blue-green ²
<i>Haliotis rufescens</i> (8)	red	white blue-green ³ pale green ³ olive green ³	pale green ³	
<i>Haliotis sorenseni</i> (10)	red	pale green	pale green	
<i>Haliotis discus hannai</i>	purple ² brown ^{4,5} yellowish brown ⁵	pale brown bluish green ⁴ green ⁵	bluish green ⁴	bluish green ⁴
<i>Haliotis gigantea</i> ⁵	brown or yellowish-brown	green		
<i>Haliotis sieboldii</i> ⁵	brown or yellowish-brown	brown or yellowish-brown		

¹ LEIGHTON, 1963² LEIGHTON, personal communication³ LEIGHTON, 1961⁴ SAKAI, 1962a⁵ INO, 1952

fed red algae. When they were fed brown algae 2 of them (one 19 mm and the other 140 mm) laid down a vivid turquoise shell (I-3, p. 83) and the other (85 mm) laid down a pure white shell.

Haliotis cracherodii: When fed brown algae this abalone laid down the deep blue-black shell described by LEIGHTON, 1963.

Haliotis assimilis: *Haliotis assimilis* was the most variable of the species studied. When fed brown algae individuals with a predominantly blue shell laid down a turquoise and white mottled shell; one individual with a large proportion of red mixed with the blue background laid down a brown and white mottled shell, and one small individual (51 mm) with an orange shell continued to lay down the same color when put on a brown algal diet. When fed red algae the 2 animals with blue and white mottled shells laid down shells which were red and white and blue mottled. No results were obtained for red algae from the other *H. assimilis*.

Behavior: The first behavioral action was noticed when the abalones were brought in from the field. At this time they would draw the shell down as close as they could to the substrate and extend their epipodial tentacles as is shown in Plate 17, Figure 1 d. They would wave these tentacles rapidly through the water. If the animal was disturbed further, it would retract the tentacles and clamp the shell down to the substrate.

Feeding behavior was similar to that described by Cox, 1962. The animal would raise its shell and extend the cephalic and epipodial tentacles into the water (Plate 17, Figure 1 a). When a piece of alga touched one of these tentacles (Plate 17, Figure 1 b), the abalone turned and extended the foot in the direction of the contact. At the same time tentacular waving would increase and consequently there was an increased number of contacts between the tentacles and the food. Once the foot made contact with the alga, it pulled the piece under the shell and the animal began eating (Plate 17, Figure 1 c). Some abalones held food in this position for 12 hours without eating it. This feeding behavior occurred in all of the species used in the diet - shell color experiments and invariably in the 40 *Haliotis rufescens* studied. Feeding could be stimulated by a variety of stimuli, among them water current and light. A successful attempt at conditioning red abalones was made using light as the stimulus and will be reported in a later paper.

Small abalones (40 mm and under) probably do feed primarily by grazing since they are found under rocks and in cracks where drift algae are seldom available. In abalone cultivation efforts they are frequently fed crustose calcareous algae which are found on rocks. Abalones can distinguish the difference between food particles and non-food particles with their tentacles but not with their foot. If a glass probe, a finger or any other non-food substance

was presented to the tentacles, it would be rejected unless it had been coated with the juice of some food item. If the same substance was presented directly to the foot it would be passed under the foot and the animal would begin to feed upon it with the radula. The epipodial tentacles, followed by the cephalic and respiratory tentacles, were the most sensitive to stimulation. All of the species would graze if no other food was presented.

DISCUSSION

The growth rate of 17.13 mm annual shell increase for *Haliotis rufescens* is in remarkably good agreement with the yearly figures for other species of *Haliotis* as reported in the literature. The fact that these shells could not be grouped into year classes can be attributed to the fact that they were all greater than $7\frac{3}{4}$ inches (196 mm) in length since the California Game Laws forbid the taking of red abalones under this size by commercial fishermen. Year classes might have become evident if there had been a greater size range. The individual variation in growth rate first noted by Cox, 1962, occurred in 5 abalones used in a simple conditioning study. They were fed nearly identical amounts of *Macrocystis* daily for 160 days and grew 4.7, 6.7, 7.6, 12.2, and 16.8 mm respectively.

Shell color of *Haliotis sorenseni*, *H. rufescens*, *H. corrugata*, and to some extent, *H. cracherodii* varies with the diet. Red algal diets are recorded in the shells by red shell color. It would be interesting to raise these species on a diet of blue-green algae to see if the similarity in red and blue-green photosynthetic pigments would result in the same red shell color. Anything but red algal diets results in a variable color which is usually a turquoise blue or off-white. *Haliotis assimilis* presents a more complicated situation and the results of this study indicate that although diet plays a role in shell color, there may be some genetic control over the capabilities of the individual abalone. The genetics of this species would be extremely interesting since there appear to be several easily distinguishable phenotypes.

In using the banding patterns of a haliotid species as an indicator of algal abundance, care should be taken to choose a species where the diet effect is readily apparent and not masked by the genetic makeup of the animal.

Many characteristics of the feeding behavior are similar to the escape behavior in *Haliotis rufescens* and *H. assimilis* described by MONTGOMERY (1967). It is curious that he has not mentioned the defensive behavior described in this study. This defensive behavior, with the shell retracted and the tentacles extended to their maximum, appears to allow the abalone to test the environ-

ment for danger while exposing itself to a minimum of that danger. The marked similarity between the defensive behavior and the feeding behavior demonstrates how an animal with a limited behavioral repertoire meets the demands of a complex environment.

Abalones held in captivity would graze only when no other food was presented. Normally they fed by finding pieces of algae with their cephalic and epipodial tentacles and capturing these algae with their foot. They then pulled a piece under the foot before eating. This is apparently the normal method of feeding as evidenced by the following observations from the commercial fishery. Abalones are normally found clamped on a "scar" on the rocks, a scar which they have grazed to the bare rock. The algae around this scar show no signs of grazing. The second observation is that commercial abalone fishermen normally find a large proportion of their catch with a piece of *Macrocystis* clamped to the bottom of the foot, even in areas above and below the range of this kelp species. These pieces could only have been carried to these areas by surge and current. Commercial fishermen also report frequently seeing the abalones raised off the bottom, apparently feeding, during the day, although most workers feel that abalones are most active at night. These drift algae are sufficient to support populations of abalones since pockets of them are found in healthy condition in areas devoid of algae. It would also account for Cox's (1962) figure of 540 feet as the lower limit of *Haliotis rufescens* distribution, although this level is several hundred feet below the photic zone given by DAWSON (1966). More likely this figure is a misprint of CURTNER's (1919) figure of 240 feet.

This feeding behavior probably resulted in the annual cycle of *Nereocystis* being recorded in red abalone shells from Morro Bay, California (OLSEN, 1968). The preservation of the cycle can probably be regarded as an artifact of the heavy local fishery. The fishermen cause many stipes to sink to the bottom where the abalones can get them.

This study has presented some information on the effect of diet on shell color for 3 previously unreported species. This information, along with the observations of feeding behavior, should serve to make the technique of using shell banding patterns in ecological studies more available to investigators from a variety of locales.

SUMMARY

The annual cycle of the brown alga *Nereocystis luetkeana* has been recorded as a regular pattern of colored bands in the shells of the red abalone, *Haliotis rufescens*. A

dating system based on this information could be useful to sublittoral ecologists if certain assumptions about abalone feeding behavior are satisfied. Abalones feed by trapping particles of macroalgae in the drift instead of by grazing. The effects of variation of the algal diet on the shell color of abalones has been discussed by several authors and is expanded here to include several heretofore unreported species. Growth rates of 45 *H. rufescens* have been determined by an indirect method and compared to other rates reported in the literature. *Haliotis* growth rates are markedly similar between species.

ACKNOWLEDGMENTS

I would like to thank Barbara Johanson for help in programming, Larry Liddle for moral support and help in caring for the abalones, Chuck Sites for furnishing the abalone shells from Morro Bay, and my wife Susan for typing and other assistance.

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Haliotis pourtalesii DALL, 1881 from Florida Waters

BY

CHARLES J. GUICE

Fishery Biologist

Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas 77550¹

(Plate 18)

THE RARE ABALONE, *Haliotis pourtalesii* DALL, 1881, previously has been collected in the Gulf of Mexico on the steep continental slope bordering the Yucatan and Florida Straits (FOSTER, 1946; HARRY, 1966). Also, PARKER (1960) illustrated a fragmented shell of *H. pourtalesii* taken from a calcareous bank in the northwestern Gulf.

On April 21, 1967, personnel of the U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries dredged a specimen from 45 fathoms on the continental shelf of Florida at Latitude 24°56.8' N, Longitude 83°40' W. The specimen was taken about 100 nautical miles west-northwest of the location reported by FOSTER (1946) and 20 fathoms shallower than any previous record. Although about 200 bottom grabs were taken along 8 transects from 5 to 1800 fathoms between St. Petersburg and Key West, Florida, *Haliotis pourtalesii* occurred in only one sample.

The specimen is illustrated in Plate 18. Shell dimensions are: Height, 8 mm; maximum diameter, 30 mm; and minimum diameter, 21 mm. There are 28 pore tubercles, 6 of which are open. The color of the shell is

brick red, with irregular splotches of tan scattered between the line of pores and the columellar border. The apex has a well-defined protoconch, pore tubercles, spiral and shoulder threads.

The specimen is deposited in the museum of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas. Identification was verified by Dr. Harold Harry, Texas A&M University.

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¹ Contribution No. 268, Bureau of Commercial Fisheries, Biological Laboratory, Galveston, Texas.

Explanation of Plate 18

Dorsal View of *Haliotis pourtalesii* DALL, 1881

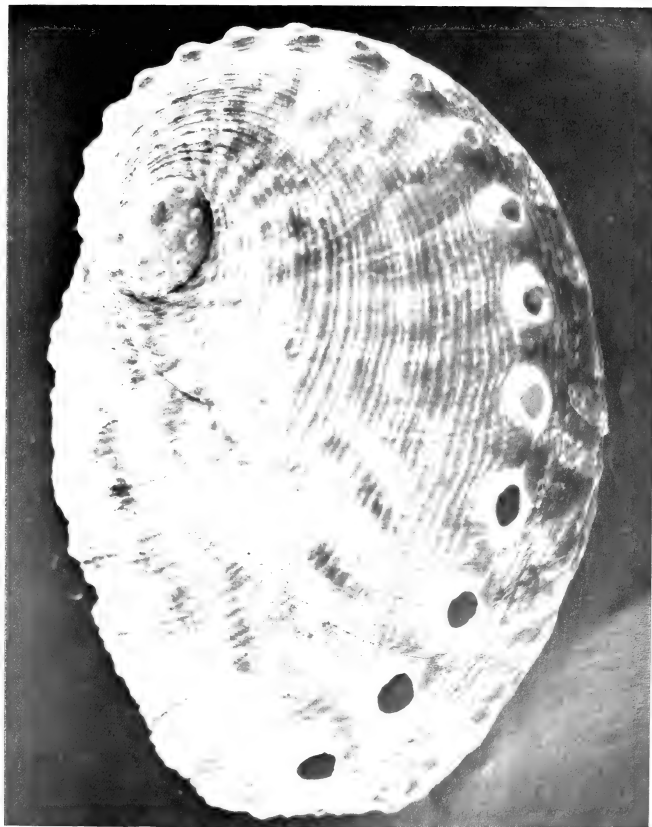


Figure 1

Removal of Pea Crabs from Live Oysters by Using Sevin®

BY

JAY D. ANDREWS
DONNA TURGEON

AND

MARIAN HREHA

Virginia Institute of Marine Science, Gloucester Point, Virginia 23062

Minchinia nelsoni, A HAPLOSPORIDIAN PARASITE, KNOWN by the anonyM MSX, caused a severe epizootic of oysters in Chesapeake Bay beginning in 1959 (ANDREWS, 1967). Old surviving oysters were dredged for breeding in 1964 but occurrence of pea crabs (*Pinnotheres ostrum*) was high. Poor condition, attributed in part to the parasitic crabs, made spawning and stripping of sexual products difficult. In the fall of 1964, progeny of these survivors being monitored for resistance to MSX also acquired serious infestations of pea crabs. Although early growth appeared normal, lots held at VIMS pier contained stunted oysters at 2 years of age in 1966. These stunted oysters often contained large pea crabs. A safe method of removing pea crabs from live oysters was needed to eliminate another variable in our field tests of oysters for disease resistance.

In 1966, Miss Hreha, a NSF summer research student, was assigned the task of finding a method for removal of pea crabs. After brief attempts with low-salinity waters, we turned to Sevin, a widely used pesticide for insects and crustaceans. Our objective was short-term exposure to kill the crabs rather than continuous exposure at low concentrations commonly used in tolerance studies. A method was developed which removes pea crabs without harming oysters.

The choice of Sevin was based on garden experience and literature which indicated low toxicity for mammals and quick detoxification. Also, we found later that Loosanoff (1961, 1965) had casually reported control of *Pinnotheres ostrum* on oyster beds treated with Sevin and chlorinated benzenes. Probably Sevin was the effec-

tive agent and he suggested use of this insecticide for pea crabs in 1961.

MATERIALS AND METHODS

For treatment, oysters were crowded in shallow pans (25 in a pan 18 by 24 by 4 inches) holding about 10 l of water. Technical Sevin (95%) in powder form was added to freshly pumped ambient sea water by stirring. Very low solubility of Sevin made concentrations to which oysters were exposed quite subjective. Periods of exposure and concentration of pesticide were gradually reduced as elimination of crabs continued successfully. Periods of time for expulsion were measured from the beginning of treatment. After exposure, oysters were held in standing or running water until sacrificed or returned to the York River. Wooden vats were used for treating trays of experimental oysters.

RESULTS

Summer Studies: Oysters 2 years or more of age were treated. Only mature pea crabs were present. Treatments were for 24 hours with 100 mg/l of Sevin followed by continued observation in trays of running sea water. Concern that oysters might not pump led to use of freshly-drawn salt water and addition of cultured algae.

Five lots of old oysters from one tray of dredged survivors of MSX were treated. Some crabs became apparent in 4 hours after Sevin was first added and most were out or protruding from oysters within 48 hours (Table 1). All samples had over 50% prevalence of crabs. Oysters extruding crabs were marked for later observations of gill and palp damage. Damage by mature crabs to gill lamellae was always quite evident (see STAUBER,

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¹ Contribution No. 281 from the Virginia Institute of Marine Sciences

1945). No additional crabs were found when oysters were opened after 72 hours. All crabs were dead.

Table 1

Expulsion¹ of Pea Crabs by Old Mobjack Bay Oysters exposed 24 hours to 100 mg/l of Sevin (2 to 12 August 1966)

No. of oysters	Number of pea crabs expelled in 24 hrs.	48 hrs.	72 hrs.	Total
25	9	2	3	14
25	9	5	1	15
25	12	1	1	14
27	12	7	1	20
27	10	3	2	15
Total: 129*	52	18	8	78

¹ Defined as first appearance of pea crab along valve margins.

* Pea crabs in 60% of oysters

Mature crabs were slowly extruded (often visible several hours on shell margins) after compression by valve action or decay. Most crabs were pushed out the ventral margin opposite their position posterior to the palps in the oysters. Legs usually appeared first but sometimes the orange-red egg sponges were the earliest parts visible.

Smaller oysters (2-year-olds) yielded 26 crabs from 97 oysters, of which 4 came out on the fourth and fifth days. The crabs ranged from 4 to 15 mm but only 2 were less than 9 mm. These oysters were not sacrificed because they were progeny being monitored for resistance to MSX. The treated oysters, returned to trays in the York River, exhibited no differences from controls in growth and mortality during the subsequent year. Other groups gave similar results, with all crabs dead or dying even when found inside oysters.

Winter Experiments: The winter experiments focused on small crabs in dormant oysters whereas the summer studies involved large crabs and active oysters. In the winter of 1966/1967, attention was given to removal of immature crabs after a rather heavy late-summer infestation of oysters at VIMS pier. Our objectives were to determine the effects of temperature, dosage of Sevin, length of treatment, and method and timing of ejection of small crabs. Crabs of the 1966 year-class (prehard to stage III and 1.6 to 5.2 mm in carapace width) were easily distinguished from older mature ones (stage V and 8 to 15 mm). Descriptions of small crab stages are given by STAUBER (1945) and CHRISTENSEN & McDERMOTT (1958).

We were concerned about effects of dosage and length of exposure time on oysters in winter because running water could not be used effectively. Oysters were inactive at ambient winter temperatures of about 5°C and warming to induce pumping was presumed to be necessary.

In a series of experiments, dosage was reduced from 100 mg/l to 50, 25, and 10 without change in effectiveness and timing of expulsion. Furthermore, treatment with Sevin was reduced from 48 hours (crabs were ejected more slowly in winter) to 12 hours with complete elimination of crabs thereafter. At first pan water was warmed to room temperature and cultured food added before treating oysters. However, oysters placed in ambient river water with Sevin added and allowed to warm for 12 hours at room temperature pumped sufficiently to kill and expel small crabs within 48 hours (water changed to remove Sevin at 12 hours). Small crabs (< 5 mm) were ejected intact (sometimes moribund) beginning about 12 hours after initial treatment and usually removal was completed in 48 hours. Large crabs (> 8 mm) took several days to be extruded, depending upon size of oysters and rate of decay of pea crabs.

In all experiments, oysters were held 48 hours or longer and pea crabs were collected frequently. It was not always possible to determine which oysters ejected small pea crabs. All oysters were opened and examined for pea crabs and gill injury. Almost without exception and regardless of size of crabs, conspicuous and characteristic gill damage was observed. Data on sexes, stages and sizes of pea crabs were collected.

Table 2

Prevalence of Pea Crabs in VIMS Pier Oysters

Date	No. of oysters	No. of pea crabs	% prevalence
Jan. 13 - 16, 1967	33	9	27.3
Jan. 26 - 31	30	22	73.3
Feb. 1 - 6	60	35	58.3
Feb. 9 - 12	40	21	52.2
Feb. 18 - 20	25	12	48.0
Feb. 21 - 24	50	33	66.0
Feb. 28 - Mar. 2	40	16	40.0
May 31 - June 7	30	7	23.3
June 26	25	5	20.0
Total	278	146	52.5

Prevalences in 1964 year-class oysters attached to pilings at VIMS pier are given for the winter of 1967 (Table 2). Oysters were treated with various dosages of Sevin for 12 to 48 hours and were opened from 2 to

several days after first treatment. The small crabs were nearly always out in 48 hours but large crabs were found dead or dying in opened oysters. All crabs were expelled if oysters were held a week or more, even at ambient (winter) water temperatures. Only 11 of 146 pea crabs in Table 2 were stage V crabs (6 to 12 mm). The rest were 1966 year-class pea crabs (prehard to stage III). The decrease in prevalence between winter and June samples is probably due in part to disappearance of males which were last found in the May 31 lot (see CHRISTENSEN & McDERMOTT, 1958). Possibly tiny crabs were overlooked in the first sample, thereby accounting for the low prevalence, or oysters from a higher level on pilings may have been used.

RECOMMENDED TREATMENT

Our purpose was to find a program of treatment which would remove pea crabs from oysters without injury to the hosts. We sought a simple and quick method for experimental purposes only. Oysters pumped freely in Sevin concentrations up to 100 mg/l. Use of Sevin in a fine hydrophobic powder state raised questions about the concentration in solution. LOWE (1967) states that the reported solubility of Sevin in water is less than 99 mg/l. Hence, all of our experiments were conducted within the probable solubility range of Sevin although not all flakes were dissolved, particularly at 100 mg/l despite limited stirring.

In October 1967 and April 1968, experiments were performed using Sevin powder and Sevin dissolved in 50 ml of acetone at 1 and 10 mg/l. Only mature pea crabs of the 1966 year-class were available in oysters because infestation by pea crabs failed completely in 1967 in lower Chesapeake Bay. Acetone appears to hasten the appearance of pea crabs being extruded between the valves of oysters but both treatments were equally effective in eventual removal of the parasites. For example, Brown Shoal oysters with a prevalence of 13 pea crabs in 25 oysters, were treated with 10 mg/l of powdered Sevin on Tuesday. By Friday 1 pea crab was out and another visible. Then the oysters were placed in the York River to stimulate pumping and were opened Monday. Seventeen of 26 oysters showed typical gill erosion and only 1 decaying pea crab was found. Mature pea crabs cannot physically pass between the valves of oysters until they are mashed or rotted into a collapsed state.

For simplicity we recommend treatment for 24 hours with 10 mg/l of powdered Sevin in ambient sea water. Oysters should then be placed in natural waters where vigorous pumping will occur and pea crabs be expelled.

DISCUSSION

Pea crabs are killed when the oyster hosts are exposed to 10 mg/l technical Sevin in freshly drawn sea water for 24 hours. After this exposure, oysters may be returned to ambient conditions with a high probability that pea crabs will be eliminated. Salinity and temperature levels are not crucial provided the oysters pump. In winter, standing sea water should be allowed to warm from ambient temperatures during treatment. Attempts to accelerate pumping with artificial food were ineffective and unnecessary.

Sevin is toxic to pea crabs at concentrations of less than 10 mg/l as it is to other arthropods and fish (LOWE, 1967). Pea crabs in oysters were killed with 1 mg/l Sevin in acetone in one experiment. Heavier dosage seems to provide quicker response in terms of appearance of large pea crabs being ejected from oysters. For our purpose, a dosage of 10 mg/l for limited periods seems reasonable in view of rapid hydrolysis of Sevin. Although 12 hours has been adequate for killing crabs in oysters, 24 hours provides some margin for oysters which may be slow to resume pumping, and longer exposure does no harm. No attempt has been made to determine critical toxicity levels for oysters or crabs because chronic exposure is not desirable or necessary. No consideration was given to testing oysters for Sevin or its derivatives since the method is intended only for experimental purposes.

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New Northern Limit for the Limpet, *Acmaea digitalis*

BY

WILLIAM F. JESSEE

School of Medicine, University of California, San Diego
La Jolla, California 92037

DURING THE RECENT Bering Sea Expedition of the research vessel *Alpha Helix*, there was some brief opportunity to examine the intertidal fauna of the southern coast of the Bering Sea. The intertidal zone in this region presents an extremely hostile environment in comparison with either the strictly terrestrial or the strictly marine zones. During the winter, intertidal invertebrates are exposed twice daily to submergence in water of temperatures from $+2^{\circ}$ to -1.5° C, followed by exposure to air in which temperatures of -10° C or lower are quite common. Survival and propagation under such conditions is indeed remarkable.

In mid-March, 1968, 6 specimens of the limpet *Acmaea digitalis* ESCHSCHOLTZ, 1833 were collected from the rocks along the shore of the enclosed bay at Dutch Harbor, on the Bering Sea side of Unalaska Island. The area of collection was at a latitude of about $53^{\circ}50'$ N. Air temperatures ranged from a daily high in the mid-thirties (Fahrenheit) to an early morning low of $+15^{\circ}$ to $+20^{\circ}$ F. The animals collected were unremarkable in any aspect of their morphology, and were definitely identified as specimens of *A. digitalis*. The largest specimen measured 25 mm in length, 18 mm in width, and 15 mm in height.

As far as can be determined from the literature, this is the first instance in which *Acmaea digitalis* has been reported from the Bering Sea. TEST (1945, 1946) cites *Acmaea* as being a Pacific genus with the northern limit of distribution of *A. digitalis* being the Aleutians. Earlier works (DALL, 1871, 1878) appear somewhat contradictory in their descriptions of the distribution of this species, but in no instance does reference appear to its occurrence on the shores of the Bering Sea. DALL (1871) states that the northern limit appears to be Cape Spencer (near Juneau), a region of much milder climate than Unalaska Island. Attempts to locate specimens of *Acmaea* species further north, through colleagues in Nome and on the island of Nuniwak, were unsuccessful. Although their reports are most likely correct, personal confirmation of

the absence of *Acmaea* in these areas is not available at this time.

That an intertidal species should have such a wide distribution as does *Acmaea digitalis* seems truly amazing. At the southern extreme of its distribution, near San Diego, California, individuals may be exposed to temperatures as high as 35° to 40° C during summer low tide periods, while at Dutch Harbor the animals are subject to winter low tide temperatures considerably below the freezing point of sea water. It is hoped that studies on temperature tolerances, desiccation, and freezing resistance in this species can soon be undertaken.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Professor Per F. Scholander, director of the Physiological Research Laboratory of Scripps Institution of Oceanography, for the opportunity to participate in his phase of the Bering Sea Expedition of the R/V *Alpha Helix*. This expedition was made possible by grant GB-7173 from the National Science Foundation to Professor Scholander.

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Feeding Behavior of *Corambella steinbergae*

BY

JAMES W. McBETH

Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92037

INTRODUCTION

ONE OF THE MOST COMMON nudibranchs found in the Friday Harbor region of the San Juan Islands, Washington, is *Corambella steinbergae* LANGE, 1962. In the summer of 1967 I had the opportunity to study the feeding behavior of this dorid in relation to the bryozoan, *Membranipora* sp., upon which it is exclusively found and whose color and pattern it mimics perfectly. A search of the literature yielded nothing concerning the interaction between these organisms, but it is generally agreed that *C. steinbergae* feeds upon this ectoproct.

Studies on the feeding of the Corambidae in general are also very sparse. *Corambe pacifica* MACFARLAND & O'DONOGHUE, 1929 has been reported to feed on *Membranipora villosa* HINCKES, but no detail is given (MACFARLAND & O'DONOGHUE, *op. cit.*). Similarly, a recent paper on the biology of *Doridella obscura* VERRILL, 1870 mentions only that this nudibranch is "always found in association with and feeding on encrusting Bryozoa" — *Membranipora crustulenta* PALLAS in this case (FRANZ, 1967).

The purpose of this study was to find out if *Corambella steinbergae* does, in fact, feed upon *Membranipora* colonies, and if so, to describe the feeding behavior.

OBSERVATIONS

Initial laboratory observations with a dissecting microscope revealed that *Corambella steinbergae* definitely does feed upon *Membranipora* colonies. The dorid approaches a fresh zoecium by pressing its mouth against the smooth surface of the frontal membrane. The lips are then protruded to form a water-tight attachment to the membrane. The radula begins to move in short bursts, from its normal position under the crop, out to the frontal membrane, where a breach is made. The effective rasping stroke is the posterior to anterior one, during which the large lateral spines point forward.

When a slit has been made in the outer, tough, dorsal covering of the zooid, the soft part is sucked out. Sucking is achieved by pulsating dilations of the buccal pump,

rhythmically assisted by the lips, which press on the zooid membrane, compressing the contents of the cell. Action of the radula is continued and the more solid parts of the zooid body are carried up on the radular teeth, although the radula was never seen to extend into the body cavity of the zoecium. As soon as the zoecium is emptied of living material, the radula is retracted and the nudibranch pulls its head away. The lips continue to stick to the frontal membrane for a brief moment until the suction is released. This lip protrusion can be artificially induced by forcing the head up while the animal is feeding. When a zoecium has been cleaned out, the nudibranch moves to another one and repeats the process.

Studies were also made on the potential feeding behavior of *Corambella steinbergae* on other genera of encrusting ectoprocts, but in no case was feeding observed.

DISCUSSION

The feeding behavior of the Corambidae offers a relatively untapped field of research. Detailed studies could be accomplished by growing *Membranipora* colonies on glass plates in order for the feeding process to be observed through the underside of the plate. Other interesting problems related to feeding behavior could include a comparison of the bryozoan growth rate to the nudibranch grazing rate. Tentative studies show that the colonies of *Membranipora* could support many more individuals of *Corambella* than they do, despite the presence of other predators, such as *Corambe pacifica*. Many colonies of *Membranipora* were found to be free of *Corambella steinbergae*, while others of the same size had as many as 20 individuals on them. It would, therefore, be of great interest to make a detailed, local distributional study of these organisms, as well as a study of movement and post-metamorphic settling.

Another study that demands attention is concerned with the relationship between *Corambella steinbergae* and *Corambe pacifica*. These two species have very similar physical and behavioral characteristics and are often found on the same *Membranipora* colony. It would be of great ecological interest to compare the biology of

these two nudibranchs to expose the full extent of their similarity.

SUMMARY

Direct observations show that the nudibranch *Corambella steinbergae* preys on the colonial bryozoan *Membranipora* sp. Its mode of feeding is a combination of radular and sucking action. Further possible studies on the biology of *Corambella steinbergae* are mentioned.

ACKNOWLEDGMENTS

I am grateful for the opportunity afforded me to do this study at the Friday Harbor Laboratories, University of Washington, through the aid of N. S. F. Marine Sciences Training grant 11-5055. I would like to express appreciation to Dr. J. A. C. Nicol and Dr. D. L. Ray for their help throughout the course of the study; to J. R. Lance for his valuable initial suggestions; and to Dr. D. L. Fox for his criticisms of the manuscript.

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NOTES & NEWS

A New Record of

Corambella steinbergae LANCE, 1962

BY

TERRENCE GOSLINER

859 Butterfield Road, San Anselmo, California 94960
ON MAY 16, 1968 I collected at San Francisco Yacht Harbor (Marina) one specimen of *Corambella steinbergae* LANCE, 1962. It measured 8 mm in length and was found on the *Membranipora membranacea* (LINNAEUS, 1767) which was encrusted on *Laminaria*. The range of this dorid extended from San Diego to British Columbia. The next area north of Monterey, where *C. steinbergae* was known to occur, was Puget Sound, Washington. Thus, the occurrence of this species in San Francisco Bay establishes an important intermediary location.

The specimen was identical with the original specimen described by LANCE and was very close to *Corambella bolini* MACFARLAND, 1966. The specimen has smooth rhinophores with a clear transparent dorsum marked with narrow lanes that closely resemble *Membranipora*.

My thanks to Miss Joan Steinberg who enlightened me as to the significance of the presence of this animal in San Francisco Bay and also for her help in the identification of the specimen.

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W. S. M.

THE SECOND ANNUAL MEETING of the Western Society of Malacologists will be held at the conference grounds at Asilomar State Park, Pacific Grove, California June 18 to 21, 1969. Scientific papers, symposia on related problems, and exhibits will be presented in various fields related to the study of malacology and invertebrate zoology.

Officers for the coming year who were elected at the 1968 conference are as follows: President, Dr. William K. Emerson, American Museum of Natural History; First Vice President, Dr. A. Myra Keen, Stanford University; Second Vice President, Mr. Eugene Coan, Stanford University; Secretary, Mrs. Paul O. Hughes, Los Alamitos; Treasurer, Mrs. Leroy Poorman, Pasadena; Members-at-Large, Dr. Judith Terry, Palo Alto, California and Miss Betsy Harrison, Honolulu, Hawaii.

All persons interested in malacology and conchology are cordially invited to attend and participate in the coming conference. Excellent accommodations in varying price ranges (American Plan) will be available for those making their reservations early.

For information on the conference or on membership in the Society please address the Secretary, Mrs. Paul O. Hughes, 12871 Foster Road, Los Alamitos, California 90720.

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If your address is changed it will be important to notify us of the new address at least six weeks before the effective date, and not less than six weeks before our regular mailing dates. Because of a number of drastic changes in the regulations affecting second class mailing, there is now a sizeable charge to us on the returned copies as well as for our re-mailing to the new address. We are forced to ask our members and subscribers for reimbursement of these charges; further, because of increased costs in connection with the new mailing plate, we also must ask for reimbursement of that expense. Effective January 8, 1968 the following charges must be made:

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Manuscripts received up to February 14 each year will be considered for publication in our July issue; May 14 is the deadline for the October issue, August 14 for the January issue and November 14 for the April issue. For very short papers of less than 500 words (including title, etc.) the deadlines are one month later than those given above, provided that these short notes are important enough to warrant preferential treatment. It is, however, understood that submission of a manuscript before the dates indicated is not a guarantee of acceptance.

On May 15, 1968 we published the second part of the supplement to Volume 3 and mailed it to those of our members and subscribers who, according to our records, had purchased Part 1 before December 31, 1964.

Part 2 will be available at \$3.- plus a handling charge of \$.35 (plus sales tax, for California residents). The complete supplement is available at \$6.- plus a handling charge of \$.45 (plus, again, the sales tax for California residents).

We deplore the long delay in the publication of Part 2 as it is our policy to publish as promptly as is technically feasible. But unusual and completely unpredictable circumstances over which we had absolutely not the slightest control are responsible. We also regret that the delay may have inconvenienced some of our readers who had given up hope of ever seeing Part 2 in print and therefore had their journal bound. To these readers we extend our apologies.

We are pleased to announce the publication on July 15, 1968 of a Supplement to Volume 11, entitled:

The Biology of *Acmaea*

edited by D. P. Abbott, D. Epel, I. A. Abbott and R. Stohler. This supplement is a group of 20 papers dealing with various aspects of the biology of several different species of limpets. It comprises 112 pages, 7 halftone

plates and numerous text figures, charts and tables. This supplement, like all our supplements, will be sold on separate order only. The price is \$5.- plus a handling charge of \$0.35; however, members in good standing are granted a discount of 20% on the sales price provided remittance for the correct amount is received before June 30, 1969. No discount can be granted after that date. California residents must add the appropriate amount of sales tax.

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At a Regular Membership Meeting of the CALIFORNIA MALACOOLOGICAL SOCIETY, Inc. the following policies were adopted by unanimous vote:

There will be an initiation fee of \$2.- (in addition to the annual dues) for persons joining the Society on or after January 1, 1967.

Members receive *The Veliger* free of further charges and are entitled to purchase one copy of any supplement published during the current membership year at a special discount (to be determined for each supplement).

Membership renewals are due on or before April 15 each year. If renewal payments are made after April 15 but before March 15 of the following year, there will be a re-instatement fee of \$1.-. Members whose dues payments (including the re-instatement fee) have not been received by the latter date, will be dropped from the rolls of the Society. They may rejoin by paying a new initiation fee. The volume(s) published during the time a member was in arrears may be purchased, if still available, at the regular full volume price plus applicable handling charges.

CALIFORNIA

MALACOOLOGICAL SOCIETY, Inc.

is a non-profit educational corporation (Articles of Incorporation No. 463389 were filed January 6, 1964 in the office of the Secretary of State). The Society publishes a scientific quarterly, the *VELIGER*. Donations to the Society are used to pay a part of the production costs and thus to keep the subscription rate at a minimum. Donors may designate the Fund to which their contribution is to be credited: Operating Fund (available for current production); Savings Fund (available only for specified

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BOOKS, PERIODICALS, PAMPHLETS

The Deep-Sea Bivalvia.

The John Murray Expedition 1933-34, Scientific Reports, Vol. XI, No. 3, Publ. No. 657, pp. 237 - 343, pls. 1 - 3, figs. 1 - 38 in text, May 19, 1967. Published by the Trustees of the British Museum (Natural History). by J. KNUDSEN.

Forty-four species of deep-sea bivalves from the Indo-west Pacific region are described and illustrated in this paper. Of these 39 were dredged by the John Murray Expedition and 5, chiefly in the Zoological Museum collection in Copenhagen, were collected by other expeditions.

The species are distributed into 16 families and 24 genera. Families embracing the largest number of species are the Pectinidae (9) and the Cuspidariidae (8). Six species are described as new: *Tindaria murrayi*, *Spinula filatovae*, *Amussium sewelli*, *Pitar sewelli*, *Xylophaga murrayi* and *Lyonsia murrayi*.

Most of the specimens were recovered from depths below 400 m. The minimum and maximum depths reported for stations from which the assemblage was obtained were 196 and 3872 m respectively. Remarks on the systematics, observations on the soft parts, and reproductive development of the various species are included as well as distribution, bottom content and temperature.

Four, possibly 6, are widely distributed abyssal species. Four were from the Red Sea, but 3 of these also live outside that area. Thirty-four are bathyal of which 10 range to East Africa and to Japanese waters. The author of the paper mentions that the bathyal bivalves suggest the existence of an Indo-West Pacific fauna having the

same range as the adjacent shallow water fauna but distinct from the bathyal bivalves of New Zealand, Australia, and South Africa.

Twenty species were found to be carnivorous. Seven of these, whose stomach content revealed small crustaceans (copepods, ostracods) and foraminifera, belong in the Pectinidae; 13 other species belong to the Septibranchia.

An interesting distribution is given for *Amygdalum politum* (VERRILL & SMITH) (pp. 269-272, text figs. 14 and 38 [map]), from Japan to the Red Sea, east and west Africa, western Europe and in the western Atlantic off eastern United States.

A species of special interest to west American workers is that cited as *Cryptodon bisecta* (CONRAD, 1849), (pp. 284, 325, pl. 2, figs. 7, 8), from the south Arabian coast and from the Banda Sea. Conrad's species was originally described from strata of middle Miocene age at Astoria, Oregon. It has been reported as a fossil at other localities in western North America, western Panama, Japan, Kamtschatka, Spitzbergen, and Colombia. In the synonymy of *C. bisecta* in the present paper are included both *C. investigatoris* E. A. SMITH, 1895, originally described from the Indian Ocean, and *Conchocele disjuncta* GABB, 1866, originally described from strata of late Pliocene or early Pleistocene age at San Pedro, California.

Most west American authors currently consider the Recent species cited in the literature as *Thyasira bisecta* living in west American waters to be referable to *Thyasira disjuncta* (GABB) (*Conchocele disjuncta* GABB, 1866), an assignment discussed by TEGLAND (Nautilus, vol. 41, pp. 129-130, 1928). The shell of this species differs from that of *T. bisecta* in that the anterior end is steeply truncated rather than rounded and projecting. *Thyasira disjuncta* also has been reported living in Japanese waters and recently BOSS (Bull. Mar. Sci., vol. 17, no. 2, pp. 386 to 388, 1967) reported it living in Caribbean waters in the Gulf of Darien off Colombia at depths of 421-641 m. In view of the variation and wide distribution reported by various authors for these large forms of *Thyasira*, further study of their identity and range is desirable.

A survey of the deep-sea bivalves of the R. I. M. S. *Investigator* and a pertinent list of references are included in this interesting contribution to knowledge of deep-sea Pelecypoda.

LGH

Lavori della Società Malacologica Italiana

Volumes 1 to 3. Milano, 1964-1966. \$12.00, Dr. Fernando Ghisotti, Via Grotto, 9, Milano.

This collection represents the rebirth of an Italian malacological journal, replacing the long defunct *Giornale*

di Malacologia (Pavia, 1853-1854), *Bullettino Malacologico Italiano* (Pisa, 1868-1874), and *Bullettino della Società Malacologica Italiana* (Pisa, 1875-1895). Following the establishment of the European Malacological Union, the Italian contingent, led by Sacchi (Naples) and Ghisotti (Milan) formed a society in 1963.

The first two volumes consist of reprints of articles published in other Italian scientific journals, the most notable paper is by Sacchi on the origin and evolution of the molluscan fauna of the southern Apennines which originally appeared in 1963 in the Annual of the Institute and Museum of the University of Naples.

The first convention of the society took place in September 1966, and volume 3 of the *Lavori* includes the original articles, some with descriptions of new species, which were presented at this meeting. One of the best papers was given by the French authority Lamotte. His summary of the factors contributing to the polymorphism in color and banding in populations of *Cepaea nemoralis* generated considerable interest. Phenotypic differences in color and banding are of selective significance as shown in the results of a number of experiments, and environmental conditions, such as temperature and proximity to the sea are related to the frequency of the banding; unbanded snails are more resistant to environmental extremes.

A molecular approach to the study of molluscan phylogeny was postulated by Parisi; he recounted the value of immunological experiments in ascertaining relationships between species and summarized information available on the distribution and occurrence of molluscan blood pigments. Girod and Pezzoli presented an exhaustively documented account of the ecology and distribution of two species of the hydroid *Bythinella* in Lombardy.

The first convention was dedicated to Giorgio Jan who, with Giuseppe de Cristofori, was responsible for the founding of the Milan Museum of Natural History. Conci presents a short history of that institution along with a list of Jan's published works. For American malacologists who have had references to the works of Stoppani or Brocchi, it is unfortunate to discover that the Stoppani collection was destroyed during the second World War. However, much of Brocchi's material was saved and critically redescribed by C. Rossi Ronchetti (1952-1955, I tipi della "Conchiologia fossile subappennina" di G. Brocchi. Riv. Ital. Palcont. Stratigr., Mem. V, Milano, 343 pp., 185 figs.).

Of the remaining articles, the more important include Mariani and Ravera on the trophic ecology of *Physa acuta*; Ravera on mollusks as experimental subjects in radiobiology; Torchio on stranding in cephalopods; and Carrada *et al.* on the biogeography of the mollusks of

Sardinia. Most of the articles have summaries in English, German or French.

Attention should be called to the "Schede Malacologiche del Mediterraneo," edited for the Società by Dr. Ghisotti (price for the first 11 Schede, 3 175 Lire, \$5.00; see review by S. Peter Dance, 1968, *Journ. Conch.*, 26 (4): 281-282).

K. J. Boss

The Systematic Relationship of *Pomatiopsis lapidaria* and *Oncomelania hupensis formosana*

by G. M. DAVIS. *Malacologia*, vol. 6, nos. 1-2, pp. 1-143; 32 pls.; 15 text figs. 1967.

The comparative anatomy and the potential for hybridization of the two members of related hydrobiid genera were studied, as well as the electrophoretic properties and laboratory ecology in an attempt to ascertain differences which might be of value to systematics.

On the basis of their anatomy *Pomatiopsis* and *Oncomelania* are judged to be distinct genera in the subfamily Pomatiopsinae. This is well documented in the paper.

Disc electrophoretic studies revealed the fact that the members of the two genera have specific patterns of protein components, those of the *Oncomelania* being dense and faster moving, while those of the species of *Pomatiopsis* are less dense and not fast moving.

Members of *Oncomelania* did well in laboratory culture, while the species of *Pomatiopsis* studied did not adapt well to laboratory culture. Young of *Oncomelania* grew at the rate of 0.65 mm per week with low mortality, whereas the young of *Pomatiopsis* grew at a rate of less than 0.14 mm per week, with a mortality of over 30% in 2 months.

Documentation of the findings is supported by numerous well executed drawings and graphs. The pertinent literature seems to be thoroughly reviewed.

RS

Summary of North American Blancan Nonmarine Mollusks

by DWIGHT W. TAYLOR. *Malacologia*, vol. 4, no. 1, pp. 1-172; pls. 1-8; 18 text figs.

The author reviews all known North American nonmarine mollusks of late Pliocene and early Pleistocene (Blancan) age. Lists of last appearances of genera and families are given. About 50 or so Blancan assemblages together with 10 to 15 older or younger faunas (these included

for convenience of discussion) are summarized under 57 local geographic headings.

On pp. 132 and 133 taxonomic changes are listed; among these are: 1 new genus (*Savaginius*); 3 new subgenera (*Calibasis*, *Oreobasis* and *Idabasis*, all subgenera of *Juga*); a new species (*Planorbella wilsoni*) and a new family (Pliopholygidae in the Viviparacea).

New names are proposed as follows: *Juga chrysopylica* for "*Goniobasis rodeoensis*" of HANNA, 1923, not of CLARK, 1915; and *Radix intermontana* for *Lymnaea idahoensis* YEN, 1946 non HENDERSON, 1931.

There are 54 taxonomic changes in classification including 20 species being synonymized and the remaining changes involving transfers of species to other genera, restoration of a family, and other clarifications of status. About 20 pages are taken up by the list of references.

RS

Notice des Titres et Travaux Scientifiques (1941-1966)

by DENISE MONGIN. Apparently privately printed; pp. 1-78; 7 figures. Paris, July 1967.

This brochure contains a complete list of papers, both published as well as unpublished ones, of Dr. Mongin. With each title is given a brief abstract. There is a list of the new taxa proposed by the author, i.e., 3 new genera and 23 new species; this list is followed by a detailed list of the collections containing the fossils studied by this author. In all, 50 papers are listed, comprising from 2 or 3 pages to about 500 pages. These papers are the result of 25 years of active scientific work by Miss Mongin.

Of special interest to the reviewer is the statement by the author of her philosophy which guided her in all her work. She states that in the course of her studies of fossil mollusks her views were always oriented toward a biological and ecological interpretation of the collected faunas and a reconstruction of the bathymetric conditions of the marine deposits and from these the paleogeography of the epoch under study.

RS

Les Mollusques du Bathonien Saumâtre du Moyen-Atlas

by DENISE MONGIN. Notes et Mémoires du Service géologique du Maroc, no. 200; pp. 35-95; pls. 1-5, 1967.

New species described are: *Isognomon marocanus*; *Eomiodon gardeti*; *Neomiodon skouraensis*; and *Terebrella*

falloti. The treatment of the species is in the best taxonomic tradition and all species discussed – not only the new ones – are beautifully illustrated.

RS

**Der Schwimmvorgang bei
Gasteropteron rubrum (Rafinesque 1814)**

by H.R. HAEFELFINGER & A. KRESS. *Revue Suisse de Zoologie*, vol. 74, no. 3: pp. 547-554; 4 text figs.

Gasteropteron rubrum, an opisthobranch, occurring in the Mediterranean and in the Atlantic, lives primarily on slimy bottoms in depths of 50 to 80 m, but occasionally is encountered on rocky bottoms. Although this species has been observed at times in great numbers in the vicinity of Banyuls-sur-Mer, the authors were able to obtain but a single specimen over a period of 30 months during which they sought it intensively. The specimen observed and photographed was obtained while dredging over a coralline bottom in about 50 m depth on May 30, 1964. The swimming activity was filmed at 24 frames/second.

It was observed that the parapodia are used in a manner comparable to the fluttering of butterflies. They perform a few strong motions, lasting about 30 to 40 seconds, after which time the motions may become weaker or stop altogether for a rest period of 20 to 30 seconds. During this quiescent period the animal slowly sinks to the bottom. The parapodia are extended sideways like wings. Such swimming could be induced by disturbing the resting animal; however, the animal also could start the swimming spontaneously.

The swimming of *Gasteropteron* was compared with that of other opisthobranchs and it was noted that it is similar to that of several listed species, but differs from that of *Notarchus punctatus*. That species seems to swim by the principle of repulsion.

RS

**Die embryonale Ausgestaltung
der frühen Mitteldarmanlage von *Octopus vulgaris* Lam.**

by SIGURD V. BOLETZKY. *Revue Suisse de Zoologie*, vol. 74, no. 3: pp. 555-562; 5 text figs.

In this paper the development from stage VII to stage XII (stage designation according to NAEF, 1921) is presented. It was noted that the formation of the mid-gut complex in *Octopus* is essentially the same as it is in decapods.

RS

**Beobachtungen über den Feinbau des Schulpes
von *Sepia officinalis***

by IGNAZ KÄLIN. *Revue Suisse de Zoologie*, vol. 74, no. 3: pp. 596-602; 3 text figs.; 1 plt.

The author demonstrates that the supporting elements in the swelling ("Wulst") of the cuttlebone of *Sepia officinalis* are not pillars, but rather ramified bands which are not closed in themselves. They differ in length and in their meandering form in the dorsal and ventral portions of the chambers. The crossing of wide and narrow meandering bands on the dorsal and ventral sides of the septa are of utmost importance in the supporting task in the cuttlebone. Where the bands meander widely, the connection of the bands is strong, whereas where they meander narrowly, the connection is weak. These observations are interpreted as pointing to the possibility that the cuttlebone is not an absolutely rigid hydrostatic system but that it may possess some elasticity.

RS

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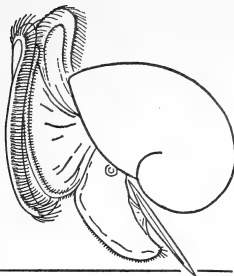
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ORDER, Suborder, DIVISION, Subdivision, SECTION,
SUPERFAMILY, FAMILY, Subfamily, Genus, (Subgenus)
New Taxa

Maturation of Gonads of Oysters, *Crassostrea virginica*, of Different Geographical Areas Subjected to Relatively Low Temperatures¹

BY

VICTOR L. LOOSANOFF

Pacific Marine Station, University of the Pacific, Dillon Beach, California 94929 *
and

Bureau of Commercial Fisheries, Biological Laboratory, Milford, Connecticut 06460

(Plates 19 to 25)

INTRODUCTION

THE QUESTION OF PHYSIOLOGICAL VARIANTS in natural populations of a species has interested biologists for a long time. The problem was well summarized by PROSSER (1955) who stated that, regardless of the general interest, the variations in physiological characters of races, or subspecies, have rarely been studied systematically. This lack of research is unfortunate because a comparison of physiological adaptations and requirements of closely related forms should contribute much to the understanding of intraspecific relations. PROSSER, nevertheless, named several criteria used in distinguishing subspecies, and indicated that the response to temperature was one to be considered. My article deals with several aspects of gonadal development of oysters, *Crassostrea virginica* (GME-LIN, 1791), of widely separated geographical areas, subjected to several different, relatively low temperatures.

The existence of physiologically different groups within the general population of *Crassostrea virginica* was first suggested by COE (1934) during his studies of alternation of sexuality of these oysters. Long before Coe's statement was made, however, practical biologists noticed certain differences among the oysters of different areas of the Atlantic Coast. For example, WELLS (1925), who discussed this matter at some length, stated that an oyster planter of New England or New York would prefer

oysters originating in certain locations: "Today a bushel of seed from the famous Bridgeport bed will command double the price of Delaware or Chesapeake seed" (p. 19). Several years later, in studying spawning of Long Island Sound oysters LOOSANOFF & ENGLE (1942) concluded that this population was not homogeneous in its spawning behavior but consisted of different groups, perhaps races or subspecies, some of which required a higher temperature than others for completing maturation of their gonads and initiation of spawning. This opinion was shared by STAUBER (1947, 1950) who, using information available in the literature on spawning of oysters of different areas, came to the conclusion that there are probably several physiologically different races within the general population of *C. virginica* of our Atlantic Coast.

The question remained speculative until LOOSANOFF & NOMEJKO (1951) presented the first evidence on the difference in temperature requirements for gonad maturation in several groups of *Crassostrea virginica*. These authors, working with oysters that originated in Massachusetts, Connecticut, New Jersey, and Virginia, demonstrated that, even though all the mollusks were of the same species, the temperature requirements for gonad development and successful spawning of the northern groups were lower than for groups living in warmer, southern waters. Preliminary examination of data based on new and much more extensive studies, in which samples again represented populations of different areas of our oyster producing belt from the Gulf of Mexico to Cape Cod were used, supported the original conclusion (LOOSANOFF, 1958a). Moreover, it is now generally ac-

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* Present address: 17 Los Cerros Drive, Greenbrae, California 94904, U. S. A.

cepted that there are physiological subspecies in *Ostrea edulis* LINNAEUS, 1758 (KORRINGA, 1957) and *Crassostrea gigas* (THUNBERG, 1793) (IMAI & SAKAI, 1961) which differ in their responses to environmental factors. Recently, HILLMAN (1964) working with two groups of oysters, one indigenous to Long Island Sound and the other to James River, Virginia, offered additional evidence, based on chromatographic studies of intraspecific serological differences in *C. virginica*. A year later the same author (HILLMAN, 1965), using oysters representative of Long Island Sound, Delaware Bay, several sections of Chesapeake Bay, Virginia, and Louisiana, further demonstrated inherent metabolic differences among the populations.

MATERIALS AND METHODS

This article is based principally on the results of experiments performed and material collected while I was at the Bureau of Commercial Fisheries Laboratory, Milford, Connecticut. Additional material has been collected, however, and practically all microscopic examination and study of about 1500 histological preparations of gonads of oysters, as well as the analysis of the data, have been completed more recently, since I became associated with the University of the Pacific Marine Biological Station at Dillon Beach, California.

Some of the oysters used in these studies came from Long Island Sound. Others were shipped from New Jersey, Virginia, North Carolina, and Florida. All oysters were mature and were 3 to 6 inches long. Except for the lot from Florida (which was sent on November 5), they were shipped to Milford during the second half of September or early in October after, or near the end of, the spawning period.

The sources of the different lots of oysters were as follows: Long Island Sound, dredged in Milford Bay at a depth of about 30 feet; Miah Maull, New Jersey; the lower part of York River, Virginia (where the salinity is about 21 ppt); the vicinity of the State Laboratory near Bears Bluff, South Carolina; and Apalachicola Bay, Florida.

Upon arrival the oysters were suspended in wire trays in Milford Harbor to recover from shipment and to complete the extremely complex physiological processes taking place in their bodies at the end of the spawning period. These processes include the resorption of gonads and accumulation of glycogen and other reserve materials before the oysters begin hibernation (LOOSANOFF, 1942). They remained in the Harbor until the middle of January and then were transferred to the laboratory and

placed in trays through which sea water of different temperatures was running at a constant rate.

Approximately 48 hours after the oysters were placed in Milford Harbor samples of gonads of all groups were taken for histological studies. All samples came from the same anatomical portion of the oyster, namely, the right side behind the line passing through the stomach on a level with the lower edge of the palps. In this way anatomical uniformity of the samples was assured. The blocks of gonadal tissue were carefully removed with a sharp razor blade to avoid pressure that could distort the tissue and produce various artifacts. The tissue was preserved in Bouin's solution and later processed by standard histological methods, sectioned at 5 μ , and stained with iron-hematoxylin and eosin.

REACTIONS OF OYSTERS TO DIFFERENT TEMPERATURES

PRELIMINARY CONDITIONING AND EXPERIMENTAL ARRANGEMENTS

Examination of the Long Island Sound oysters, made approximately 48 hours after they were placed in Milford Harbor, showed that they were nearing completion of, or had completed spawning, and many had virtually undifferentiated gonads. In this group, resorption, which follows spawning, had been completed and the oysters were accumulating glycogen and other reserve materials (Plate 19, Figure 1). A few individuals, nevertheless, still contained small quantities of spawn. Gross examination showed that the meats were healthy and all oysters had crystalline styles and food in their stomachs.

The New Jersey oysters were not as far advanced as the Long Island Sound group; they had more individuals in the late stages of gonad resorption (Plate 19, Figure 2). The majority of these oysters, nevertheless, had already completed resorption and were approaching winter condition. All oysters contained large quantities of glycogen, and crystalline styles and large quantities of food were found in their stomachs.

The Virginia oysters were, as a rule, in the final stages of gonad resorption or already displayed winter-like gonads, although a few individuals of both sexes still contained different quantities of undischarged sexual products. Many oysters contained large quantities of glycogen (Plate 19, Figure 3). This observation suggests that a lack of this material could not be the reason for the failure of Virginia oysters to develop gonads later in the season when they were subjected to the conditioning



Figure 1

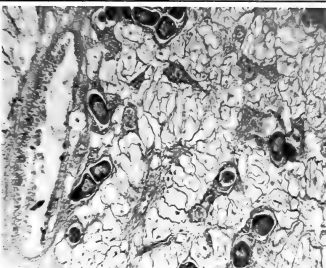


Figure 2

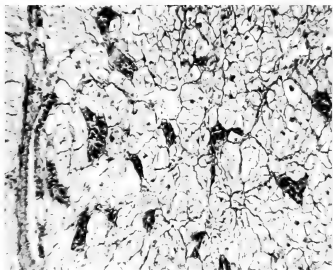


Figure 3

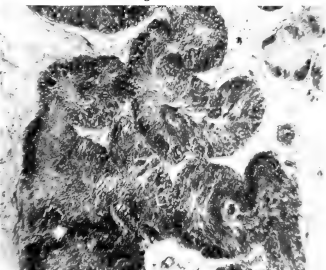


Figure 4

Figure 1: Gonad of a typical Long Island Sound oyster late in September after completion of spawning. The thin gonadal layer is confined between the body wall of the oyster and the tubules of the digestive diverticula. The small, undifferentiated gonadal follicles are surrounded by large cells of connective tissue containing glycogen. Later in the season, when the oysters have accumulated more reserve material, the glycogen-gonadal layer will become much thicker. ($\times 125$)

Figure 2: Gonad of New Jersey female oyster late in September still containing some eggs that will soon be either discharged or resorbed. ($\times 125$)

Figure 3: Gonad of Virginia oyster late in September. The small, newly formed gonadal follicles are surrounded by large masses of connective tissue. ($\times 125$)

Figure 4: Gonad of South Carolina male oyster late in September still containing a large quantity of undischarged spermatozoa. ($\times 125$)

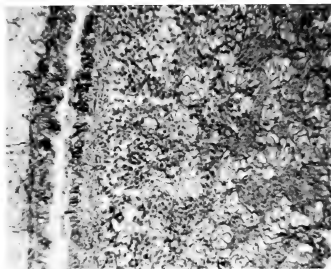


Figure 5

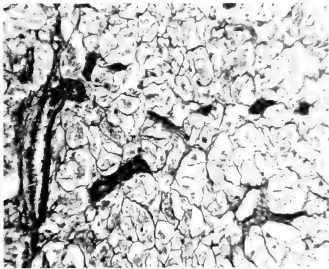


Figure 6

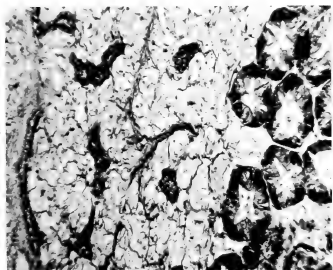


Figure 7

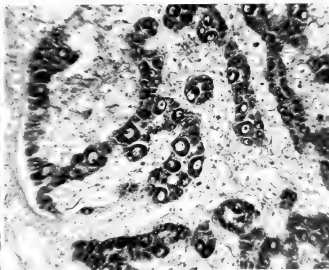


Figure 8

Figure 5: Gonad of Florida oyster collected on November 15. Gonadal follicles are virtually absent and a large portion of the entire area is occupied by leucocytes. Part of genital duct is visible. ($\times 125$)

Figure 6: Gonad of Virginia oyster collected on January 15 containing small, undifferentiated follicles and large quantities of glycogen-laden tissue. ($\times 125$)

Figure 7: Gonad of South Carolina oyster collected on January 15. ($\times 125$)

Figure 8: Gonad of one of the most advanced Long Island Sound female oysters conditioned for 45 days at 12°C . ($\times 125$)

methods employed at Milford Laboratory (LOOSANOFF, 1945; LOOSANOFF & DAVIS, 1950).

The South Carolina group was distinctly different from the 3 others described. Nearly all oysters still contained large quantities of spawn, and some appeared entirely unspawned (Plate 19, Figure 4). All were feeding well; their stomachs contained large quantities of food and all had large, well developed crystalline styles.

The first examination of the Florida oysters showed that they were in a much poorer condition than any of the previously described groups. They were "watery", and contained little glycogen or gonadal tissue (Plate 20, Figure 5). They had almost no gonadal follicles and the area between the digestive diverticula and the body wall was often filled with leucocytes or phagocytic cells. The presence of large numbers of these cells was characteristic of this group of oysters. Regardless of their poor condition, these oysters were feeding, although their crystalline styles were thin and their stomachs usually contained much less food than was found in the oysters of the other groups.

All groups remained suspended in Milford Harbor until January 15, at which time the bottom temperature was 3° C. Then, the oysters were brought into the laboratory, cleaned, and placed in trays of running water the temperature of which was about 5° C. The next day the temperature was increased to about 8° C and the oysters began to receive, as supplementary food, a mixture of phytoplankton grown in a tank of about 3000 liter capacity (LOOSANOFF & ENGLE, 1942 b).

All groups of oysters brought into the laboratory on January 15 were examined to ascertain their pre-experimental physical condition. The Long Island Sound oysters were in excellent condition, containing large quantities of glycogen; their gonads were in typical winter stage. The New Jersey oysters were in the same condition but contained even larger quantities of glycogen. The Virginia oysters were also in typical winter stage with undifferentiated gonadal follicles. None carried unspawned cells and, as a rule, all individuals had sufficient glycogen for normal development of gonads (Plate 20, Figure 6).

Although the South Carolina oysters still contained much spawn in September, by January 15 it was either entirely discharged or (more probably) resorbed in all individuals. Therefore, at the beginning of the conditioning experiments these oysters were in about the same physiological state as those of the 3 northern groups, since these South Carolina oysters also contained sufficient quantities of glycogen for development of gonads (Plate 20, Figure 7).

The Florida oysters differed radically from all other groups because, with the exception of a few individuals whose glycogen reserve was probably adequate (although considerably less than that of the other groups), the majority displayed a very thin glycogen-gonadal layer in which a few winter-like follicles were imbedded. Large numbers of blood cells were present throughout the bodies of these oysters, much the same as is shown in Figure 5, Plate 20. No individuals were found, however, with unspawned eggs or spermatozoa.

The general plan of the experiments was to hold some oysters of each geographic group at temperatures of 12°, 15°, 18°, 21°, and 24° C \pm 1° C for different periods to determine the number of days required for maturation of their gonads, including the stage when the oysters become so ripe that they can be induced to spawn (LOOSANOFF, 1945; LOOSANOFF & DAVIS, 1963). In all trays the water temperature was increased gradually to the desired level to avoid possible physiological shock to the oysters. Positions of the trays were randomized and all trays received the same quantity of water and plankton food. Enough oysters were left in reserve for repetition of the experiments, if necessary, or for studies of the behavior of the oysters at higher temperatures. The present article discusses the observations made at comparatively low temperatures, namely, 12°, 15°, and 18° C \pm 1° C.

In evaluating the condition of the oysters of the different groups, especially those of Florida, it was anticipated that many might be heavily infested with parasites, such as *Bucephalus*, or disease-causing forms, such as *Dermocystidium*. Because these organisms may adversely affect gonadal development, it was decided to base final conclusions only on those oysters which, upon microscopic examination, showed no easily recognizable parasites. It was realized, nevertheless, that even this precaution to achieve a fair approach in estimating the gonadal development was not entirely reliable because the numerous microorganisms that may affect oysters are not fully known. Nevertheless, the decision to base conclusions on only those oysters that appeared healthy helped, undoubtedly, to estimate more fairly the condition of the experimental animals.

Two criteria were used to evaluate the rate of gonad development. The first consisted in determining the number of days required, at a given temperature, for 50% of the oysters in the sample to develop physiologically ripe spermatozoa or fertilizable eggs. Attainment of this state was ascertained by examination of gonadal material from each oyster as it was dissected. This material was suspended in a small quantity of sea water and examined

under a microscope to determine whether it contained eggs or sperm. Gametes of the opposite sex were then added to determine if those of the examined oyster were physiologically ripe. The sex cells for this test were always taken from the oysters conditioned at a temperature of about 24° C and known to be entirely ripe.

The second criterion, applied chiefly to higher temperatures not discussed in this article, was to determine the length of the conditioning period necessary at each temperature before 50% of the oysters in a sample could be induced to spawn. This test was accomplished by placing each oyster in an individual container and then stimulating it to spawn by a rapid increase of water temperature to about 28° C or 30° C, and by simultaneous addition of a suspension of gonadal material taken from ripe oysters. Normally, each sample, especially those taken for final examination, consisted of 50 individuals. These groups will be discussed in geographic order, the northern oysters being considered first.

OBSERVATIONS AT 12° C

On March 4, after 45 days of conditioning at 12° C, the Long Island Sound oysters were again measured and examined. All showed new growth and some, whose total length was near 100 mm at the beginning of the experiment, had grown as much as 10 mm. The meats were good and the thickness of the gonadal layer varied from 0.5 mm to 1.0 mm. All stomachs contained food and crystalline styles were present.

None of the oysters of this group spawned when subjected to thermal and chemical stimulation. A later histological examination of the gonadal tissue showed that none were ripe and that many still had typical winter gonads characterized by small follicles containing virtually undifferentiated cells. Nevertheless, some advanced females possessed oocytes measuring up to 30 μ , although most of the cells in the follicles were considerably smaller (Plate 20, Figure 8). After a total of 50 days of conditioning at 12° C a larger number of females had oocytes measuring between 25 μ and 30 μ , and in some males gametogenesis had progressed to the stage of formation of spermatids or, possibly, even a few spermatozoa. Even though the thickness of the gonadal layer of the most developed oysters was 1.5 mm, none could be induced to spawn.

The next group of Long Island oysters was examined after being kept for 61 days at 12°. They were subjected to spawning stimuli, by slowly raising the temperature of the water and holding it near 30° C for 2 hours, and by the addition of sperm and egg suspensions. None spawned.

Histological examination of the gonad showed that the oysters varied greatly in degree of ripeness. Some females contained many eggs measuring 45 μ , but the majority had unripe gonads in which the largest oocytes were only about 15 μ in diameter. Spermatozoa were found in several males (Plate 21, Figure 9). None of the ripe eggs of the normal females, to which sperm of the 12° C males was added, were fertilized, however, even though the sperm remained active for at least 2 hours. It was also noted that most of the spermatozoa suspended in the water were still connected by the heads in groups of 2 or 4, probably because they were not entirely ripe. Some of the eggs taken from the most advanced females were fertilized by sperm that came from males conditioned at a temperature of 24° C. Fertilization occurred but none of the eggs developed into straight-hinge larvae.

The first spawning of the male oysters conditioned at a temperature of 12° C was induced after 68 days. Spawning began when the temperature in the spawning dish reached 28° C. Discharged spermatozoa were apparently normal because they fertilized the eggs of females conditioned at higher temperatures; the eggs developed into normal straight-hinged larvae. The male spawned for 22 minutes, discharging a large quantity of spermatozoa.

A female was induced to spawn after 78 days. Initially, I attempted to induce spawning in this group merely by adding sperm and egg suspensions to the 12° C water in which the oysters were conditioned. When none of the oysters responded after 1 hour, the temperature was rapidly increased; when it reached 23° C, 15 minutes later, the first female responded. It was the only female that spawned in the group of 49 oysters. The eggs released were fertilized with normal sperm. Many embryos developed into abnormal larvae, which never progressed beyond the trochophore, but some reached the normal straight-hinge stage. Thus, experimental evidence was obtained that certain Long Island Sound oysters can be conditioned to ripeness at a temperature as low as 12° C.

Histological examination of the gonads of the oysters used in the spawning experiment after 78 days of conditioning showed that about 80% contained either large numbers of apparently normal spermatozoa or some fertilizable eggs (Plate 21, Figure 10) in contrast to the smaller groups that still had essentially winter gonads (Plate 21, Figure 11). This difference may indicate, as already suggested by LOOSANOFF & ENGLE (1942a), that the population of Long Island Sound is not genetically homogeneous.

The New Jersey oysters and the more southern groups were kept under the same experimental conditions as

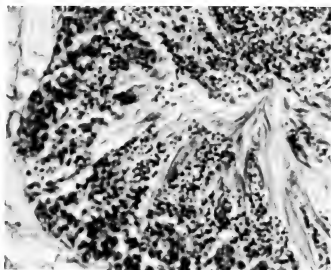


Figure 9

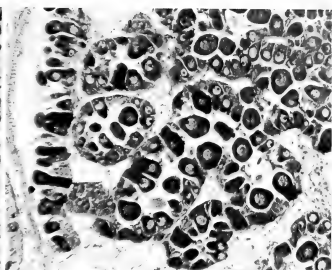


Figure 10

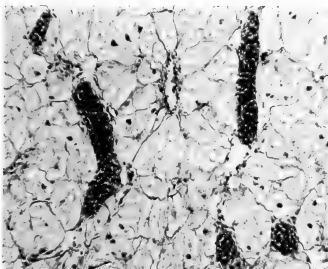


Figure 11

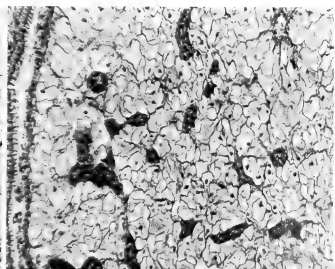


Figure 12

Figure 9: Gonadal follicle of Long Island Sound male oyster kept for 61 days at 12°C . The follicle contains ripe or nearly ripe spermatozoa. ($\times 575$)

Figure 10: Gonad of Long Island Sound female oyster conditioned for 78 days at 12°C . This individual, one of the most advanced of the group, contains some ripe eggs. ($\times 125$)

Figure 11: Gonad of Long Island Sound oyster showing almost no development after conditioning for 78 days at 12°C . The small follicles, just beginning to differentiate, are surrounded by large quantities of connective tissue. ($\times 125$)

Figure 12: Gonad of one of the most advanced New Jersey oysters conditioned at 12°C for 67 days. Note small, undeveloped follicles and large quantities of connective tissue. Genital duct is visible. ($\times 125$)

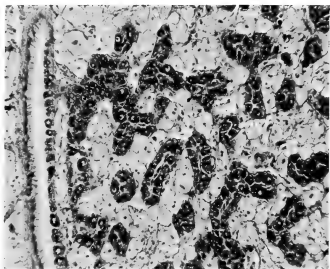


Figure 13

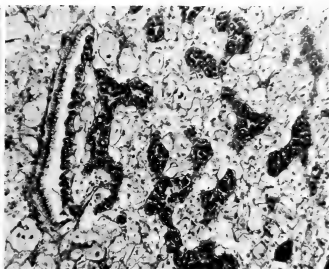


Figure 14

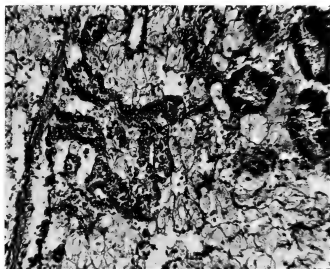


Figure 15

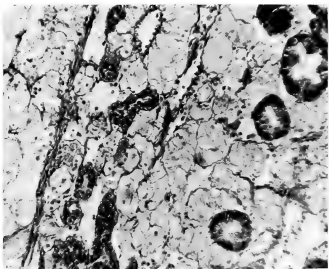


Figure 16

Figure 13: Gonad of New Jersey female oyster conditioned at 12° C for 78 days. ($\times 125$)

Figure 14: Gonad of one of the most advanced Virginia oysters conditioned for 78 days at 12° C. ($\times 125$)

Figure 15: Gonad of South Carolina oyster conditioned for 78 days at 12° C. ($\times 125$)

Figure 16: Gonad of Florida oyster after 78 days of conditioning at 12° C. ($\times 125$)



those described for Long Island Sound oysters, but the New Jersey group was not subjected to spawning stimuli until the 67th day of conditioning because microscopic examination of the gonadal material before that day always showed the absence of ripe cells. Regardless of slow ripening, the New Jersey oysters were healthy, their meats containing a large quantity of glycogen. In some the thickness of the gonadal-glycogen layer exceeded 1.5 mm. Practically all showed new shell growth; often more than 10 mm had formed since the beginning of conditioning. Food and crystalline style were usually present.

After 67 days of conditioning the oysters were subjected to a temperature between 25° C and 30° C for over 2½ hours and to regular chemical stimulation, but none spawned or made the rhythmic shell motions characteristic for females which are ripe or nearly ripe. Examination of the gonadal material revealed the presence of neither spermatozoa nor recognizable oocytes. Histological examination showed that even the most advanced individuals still possessed typical undeveloped winter gonads (Plate 21, Figure 12).

The New Jersey oysters were again subjected to spawning stimulation after 78 days of conditioning. None responded after being kept at a temperature of 25° C to 30° C for about 2½ hours. A few oocytes measuring as much as 25µ in diameter were present in about 20% of the oysters (Plate 22, Figure 13). Strangely enough, not a single ripe male was found. None of the oocytes taken from the most advanced females could be fertilized. Clearly, the New Jersey oysters were not yet ripe. The advent of spring was making it so difficult to keep the oysters at 12° C that the experiment was terminated at this time.

The Virginia oysters still possessed winter gonads even after 78 days of conditioning at 12° C. The 50 individuals that constituted the sample included only 2 with a few oocytes, the largest less than 25µ in diameter (Plate 22, Figure 14). The males of this group were also obviously too immature to be able to spawn. Again, the experiment had to be ended because of the approach of spring.

After 61 days of conditioning the South Carolina oysters differed from those of the first 3 groups by being much poorer. This condition was characterized by the small quantities of glycogen and by the thinness of the gonadal layer which in the South Carolina oysters was almost undetectable; in most it was between 0.0 and 0.5 mm. Moreover, these oysters grew much more slowly than the northern oysters; the best showed an increase in length of only about 5 mm, and at least half of the oysters showed no new growth. After 67 days at this temperature the conditions remained practically the

same; there was no increase in gonadal thickness and the oysters remained unripe.

The same situation prevailed on the 78th day of conditioning when the experiment was terminated. The sexes still could not be easily ascertained and the thickness of the gonadal layer remained at 0.5 mm or less (Plate 22, Figure 15). The final gross examination showed that the meats remained watery until the end. These oysters grew poorly or not at all. Approximately 75% had no crystalline style or food in their stomachs. Since, as is shown later, the South Carolina oysters conditioned at 15° C and 18° C contained crystalline styles and had food in their stomachs, it may be assumed that these were absent in the oysters kept at 12° C because the temperature was too low for normal feeding.

The Florida oysters resembled those of South Carolina in appearance and behavior. Throughout the conditioning period of 78 days they remained watery and poor and displayed a thin gonadal layer of only about 0.5 mm or, more commonly, even less. They also grew much more slowly than the oysters from the 3 northern areas but, nevertheless, somewhat better than those from South Carolina. At the end of the experiment no recognizable sex cells could be found in gonadal smears and, as is shown in Figure 16 (Plate 22), even the best specimens were in retarded condition. As in the South Carolina group, more than ¾ of the Florida oysters had no crystalline styles or food in their stomachs. Obviously, the Florida oysters could not reach ripeness at 12° C even after about 2½ months of conditioning.

OBSERVATIONS AT 15° C

Previous observations on the behavior of *Crassostrea virginica* at low temperatures have shown that Long Island Sound oysters can be conditioned to ripen and induced to spawn at a temperature of 15° C (LOOSANOFF & DAVIS, 1952). Nevertheless, these oysters were included in this experiment primarily to serve as the control for the more southern groups.

When, after 45 days of conditioning, the Long Island Sound oysters were exposed to spawning stimuli about 60% of them responded. Histological examination showed, however, that although many males spawned, a large portion of the sex cells in their gonadal follicles was still unripe (Plate 23, Figure 17). Females with well-developed but not fully ripe gonads were also common (Plate 23, Figure 18). Abnormalities, principally manifested by the presence in the gonadal area of a large number of phagocytes, were observed in some oysters.

The spawning experiment was repeated with Long Island Sound oysters conditioned for 50 days. About 70% spawned, many females discharged several million eggs each. These eggs, fertilized with the spermatozoa of males also conditioned at 15° C, developed into normal larvae. Gross examination of the oysters showed that they were in good condition, having gonads that averaged slightly more than 1 mm in thickness. The follicles, nevertheless, still contained large numbers of immature sex cells.

Soon after the above-described experiment a natural, unprovoked mass spawning occurred in all 15° C trays containing Long Island Sound oysters. Since we already knew that these oysters can spawn at 15° C, it was not entirely unexpected. Because these oysters had a long history of conditioning at a relatively low temperature, however, it was decided to use them in auxiliary experiments in which an attempt was made to induce spawning by chemical stimulation alone at a temperature as low as 12° C. In the first experiment 15 oysters conditioned for 59 days at a temperature of 15° C were placed in water of 12° C. After being held at this temperature for 2 hours a suspension of ripe sex products was added to the water. None of the oysters of either sex responded to this stimulation even after a 2-hour contact with the sex cells.

In another experiment a second group of 15 oysters, conditioned at 15° C for 68 days, was placed in water of 12° C and treated as were the oysters used in the first experiment. After being kept at 12° C for 1 hour and 10 minutes none spawned or showed any response to stimulation. Then, the temperature was slowly increased; when it attained 13.2° C one male began to spawn copiously. This, to the best of my knowledge, is the lowest temperature at which the American oyster, *Crassostrea virginica*, has ever been seen to spawn. Possibly, other oysters of this same group would have spawned also if a natural spawning had not occurred in the trays containing this group only 3 days before this experiment.

The New Jersey oysters conditioned at 15° C were, throughout the experiment, in excellent physical condition, containing a larger quantity of glycogen than any other group. The oysters also grew well and, after 45 days of conditioning, their new shell growth averaged about 5 mm. Microscopic examination of smears of the gonadal material, and histological studies showed that all except 2 of the oysters of this group possessed virtually undifferentiated winter gonads. Even the most advanced males were in the early stages of gametogenesis and still had only small gonadal follicles (Plate 23, Figure 19). None of the oysters spawned upon stimulation.

About 2 weeks later, after 60 days of conditioning, the oysters were examined again. Most still possessed undeveloped gonads, but one female contained a few fertilizable eggs. Only a few ripe spermatozoa could be detected in the most advanced male, and nearly all of the cells still remained in the earlier stages of spermatogenesis.

After 72 days of conditioning 20% of the New Jersey oysters could be recognized as females in early stages of oogenesis. In only 1 of 25 oysters could some of the stripped eggs be fertilized and, in general, the oysters in this group were unripe; most still displayed almost winter-like gonads (Plate 23, Figure 20). The experiment was terminated on that date. The remaining oysters were in excellent condition. Until the very end of the experiment the oysters fed vigorously, discharging large quantities of normal true feces.

None of the Virginia oysters conditioned at 15° C showed much progress at the end of 45 days. After 60 days, however, one male contained a few motile spermatozoa although most of them were connected by their heads, indicating that they were still not ripe. The rest displayed virtually winter gonads. After 70 days of conditioning none of the 25 oysters examined possessed either ripe sperm or fertilizable eggs. Histological preparations of gonads of these oysters showed that at the end of the conditioning period, which extended for 72 days, even the most advanced males were still far from being ripe; the follicles were undeveloped and small (Plate 24, Figure 21).

It is probably significant that, contrary to conditions observed in the Virginia oysters kept at 12° C, about 75% of those subjected to 15° C contained well-developed crystalline styles and large quantities of food. This difference may indicate, as previously mentioned, that the group of Virginia oysters, with which we dealt, could not feed efficiently at 12° C, whereas the temperature of 15° was high enough for them to feed actively.

At the end of the experiment the meats of the Virginia oysters were still good and contained large quantities of glycogen. Approximately 40% of the oysters did not show any new shell growth, however, a condition which was contrary to that recorded for the 2 northern groups where the oysters showed considerable increase in shell length.

The South Carolina oysters differed radically in their general condition from the oysters of the 3 more northern areas. Samples of 50 oysters examined on the 60th and 72nd days of conditioning showed that only about 20% of the individuals were in good condition, possessing a glycogen-gonad layer about 1 mm thick; 26% were medium poor (gonadal layer of only 0.5 mm), and 54% were

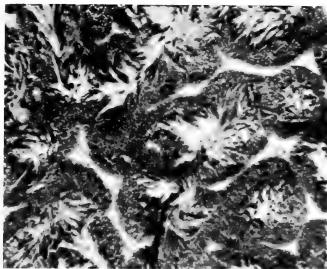


Figure 17

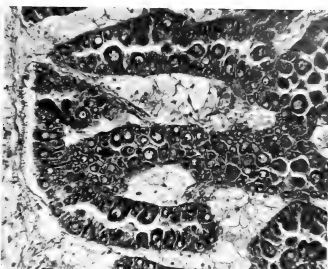


Figure 18

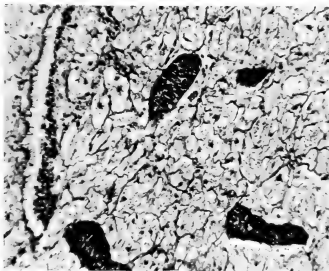


Figure 19

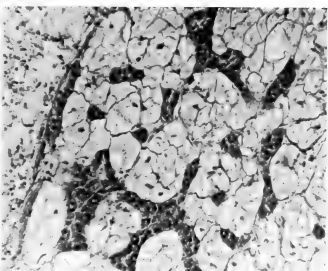


Figure 20

Figure 17: Gonad of partially spawned Long Island Sound male oyster conditioned for 45 days at 15° C. (× 125)

Figure 18: Gonad of Long Island Sound female oyster conditioned for 45 days at 15° C. Although the oyster is approaching ripeness, a majority of the cells in its follicles are still relatively small. (× 125)

Figure 19: Gonad of New Jersey male oyster conditioned at 15° C for 45 days. (× 125)

Figure 20: Gonad of New Jersey female oyster in early stages of ovogenesis, conditioned for 72 days at 15° C. (× 125)



watery (gonadal layer so thin that it could not be accurately measured). Only about 38% of the oysters contained food in their stomachs and possessed crystalline styles; the rest had neither styles nor food.

All the South Carolina oysters still displayed undeveloped gonads after 60 days of conditioning. Even after 72 days only 1 male of the entire sample contained some sperm and only 2 females had recognizable small oocytes. Because the rest of the oysters in the group were clearly immature (Plate 24, Figure 22), no stimulation of spawning was attempted.

Of the entire Florida group of 50 oysters conditioned at 15° C for 72 days only 8 had medium good meats; the rest were either poor or in the still lower category known as "watery". At the end of the experiment only 2 individuals had a gonadal layer about 1 mm thick; 8 had a layer of approximately 0.5 mm, and the remaining 40 oysters had no definite gonad.

The thinness of the gonadal layer was characteristic of Florida oysters. Moreover, even this layer was usually invaded by a large number of leucocytes. In general, the gonads were so poorly developed that at the end of the long conditioning period the sex of most of the oysters could not be easily determined even in the histological preparations (Plate 24, Figure 23). Strangely enough, these oysters with poor meat grew well. Only 4 of 50 oysters showed no increase in length, and several showed an increment of more than 10 mm. Thirty percent contained food and crystalline style, but some individuals lacked a crystalline style although some food was found in their stomachs.

OBSERVATIONS AT 18° C

The temperature of the third series of observations is the one at which Long Island Sound oysters, living under natural conditions, can fully develop their gonads and spawn (LOOSANOFF & ENGLE, 1940). It was not known at the time these experiments were begun, however, how the oysters of other geographic areas would behave at this temperature. Moreover, it was of interest to compare the behavior of Long Island Sound oysters at this temperature with that at 12° C and 15° C.

Examination of the Long Island Sound oysters after only 15 days of conditioning at 18° C showed that their gonads were sufficiently developed to contain easily recognizable oocytes or spermatids although, in general, the oysters were still unripe. After 21 days, however, occasional females already contained some mature, fertilizable eggs and many males had physiologically ripe spermatozoa. Three days later the majority of the oysters

contained either ripe sperm or eggs. Regardless of the presence of some ripe cells, the gonadal follicles of the Long Island Sound oysters were not fully developed at that time (Plate 24, Figure 24). Nevertheless, some oysters spawned when subjected to our usual method of stimulation.

After 32 days at 18° C 75% of the oysters in the sample were ripe enough to spawn, while approximately 15% still contained immature, winter-like gonads.

The New Jersey oysters exposed to 18° C differed radically from the Long Island Sound group of which 75% could be induced to spawn at the end of 32 days. Almost none of the New Jersey oysters, even the most advanced, contained easily recognizable sex cells (Plate 25, Figure 25) in 32 days. Strangely enough, this retarded condition prevailed even though the oysters contained much glycogen, fed well, and appeared healthy.

A few fertilizable eggs or ripe spermatozoa were found in several New Jersey oysters after 51 days of conditioning, but none of either sex could be induced to spawn. After 71 days the majority still displayed virtually undifferentiated gonads but, strangely enough, about 10% of them could be induced to spawn. Histological studies of the tissues of the unripe oysters clearly showed that, regardless of their retarded gonadal development at the end of the conditioning period, they were healthy and contained large quantities of glycogen (Plate 25, Figure 26).

All Virginia oysters exposed to 18° C for 30 days possessed undifferentiated winter-like gonads. Nevertheless, the generally good appearance of the oysters excludes the possibility that gonad development was retarded because of poor physical condition. Oysters examined after 51 and 58 days of conditioning also contained neither active sperm nor fertilizable eggs, and most displayed winter-like gonads surrounded by large quantities of glycogen-laden connective tissue cells. None could be induced to spawn. Even after 71 days at 18° C, when the experiment was discontinued, the most advanced females were still in the early stages of ovogenesis, containing follicles in which the largest oocytes were only about 10μ or 15μ (Plate 25, Figure 27). No spermatozoa were found and none of the oysters composing the sample responded to spawning stimulation.

Histological studies of the tissues preserved at the end of the experiment showed that large portions of the oysters' bodies, frequently including the gonadal area, contained unusually large numbers of leucocyte-type cells. The exact nature of this phenomenon is not understood but even if it represented a pathological condition, it did not interfere with feeding; practically all of the oys-

ters contained food in their stomachs and possessed large, normal crystalline styles.

Our lack of success in conditioning Virginia oysters for spawning during the winter was later shared by other investigators. For example, in a letter to me dated March 30, 1955, Dr. Jay Andrews of Gloucester Point, Virginia, wrote: "Could you send us a dozen oysters conditioned for spawning? We have been trying for two months to prepare Virginia oysters without success." He was sent several dozen Long Island Sound oysters which were easily induced to spawn by our usual method in Dr. Andrews' laboratory. During a recent conversation with Dr. Andrews, in January 1968, I was told that they still cannot condition their oysters for normal spawning, and that to culture the larvae of these oysters they still have to depend on stripping the gonads to obtain some ripe eggs that are later fertilized artificially.

Since the Virginia oysters kept at 18°C failed to develop ripe gonads at this temperature even after 71 days, it was anticipated that the South Carolina oysters, a more southern group, would probably react in the same way. This expectation was strengthened by the previously reported observation that these oysters when kept at 15°C did not develop fertilizable eggs or sperm, had poor, watery meats and, typically, showed a near absence of glycogen in their tissues. Examination of the South Carolina oysters conditioned at 18°C clearly showed, however, that these expectations were not justified because the meats of these oysters were considerably better than those of the 15°C group. This observation strongly suggests that a difference of 3°C within this temperature range is highly important ecologically and physiologically because the South Carolina oysters feed and assimilate food much more efficiently at 18°C than at 15°C. Possibly 15°C is near the minimal temperature for the active feeding of this geographic group. Probably a temperature of about 18°C for South Carolina oysters can be compared with the temperature level of approximately 10°C for Long Island Sound oysters, below which the water-pumping rate is significantly lower than between 12°C and 15°C (LOOSANOFF, 1958b). It should be extremely interesting to verify this possibility by repeating the experiments on rate of pumping of Long Island Sound oysters on the Virginia, South Carolina, and Florida populations.

After 30 days at 18°C the South Carolina oysters still possessed undeveloped follicles. After 51 and 58 days at this temperature, however, some of them, unlike the Virginia group kept at the same temperature, showed well-developed gonads. Although none could be induced to spawn, some males had a few spermatozoa, and some fe-

males had a few ripe eggs that could be fertilized (Plate 25, Figure 28). Strangely enough, nearly 50% of the oysters in this sample were still entirely undeveloped. They were not the poorest individuals; on the contrary, many of them showed a layer of connective tissue, containing glycogen, that was in excess of 1 mm.

Oysters of both sexes were induced to spawn after 71 days of conditioning. The spawners represented only about 15% of the sample, but ripe sperm and eggs were found in other individuals that could not be induced to spawn. Again, about half the oysters were still unripe, displaying winter-like gonads.

Samples from the most southern, or Florida, group of oysters exposed to a temperature of 18°C for a period of 71 days were examined macroscopically and microscopically on the 30th, 51st, and 71st days. All of them were poor, watery, and contained little glycogen. None showed even partially developed gonads and neither spermatozoa nor recognizable oocytes could be seen in histological preparations. A common condition in these oysters was the presence of masses of blood cells in the area normally occupied by gonadal follicles. In general, these observations showed conclusively that it was impossible under the conditions of the experiment to ripen the Florida oysters at 18°C even after 71 days of conditioning.

DISCUSSION AND SUMMARY

This article is the first comprehensive report on the progress of gametogenesis of different populations of *Crassostrea virginica* subjected to low temperatures. It shows that groups of oysters from Long Island Sound, New Jersey, Virginia, South Carolina, and Florida, kept in Milford Harbor, Connecticut, for about 3 months and then subjected to a long conditioning period at temperatures of 12°C, 15°C, or 18°C, displayed sharp differences in the stage attained in the development of their gonads. Some of the oysters that originated in Long Island Sound were able to ripen even at 12°C. After 68 days of conditioning at this temperature about 65% of these oysters contained either active spermatozoa or mature eggs. Spawning of one male was induced after this period and 10 days later a female also spawned. Some Long Island Sound oysters, therefore, can be brought to ripe condition by being kept at a temperature of only 12°C.

The New Jersey oysters and those of the more southern groups differed radically from the Long Island Sound oysters by being unable to carry on active gametogenesis at this temperature. As a rule, the gonads in most of these oysters were so poorly developed at the end of 78 days

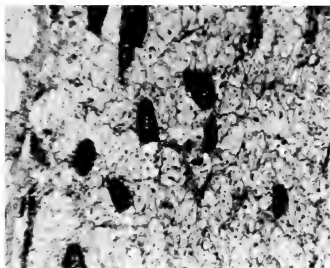


Figure 21

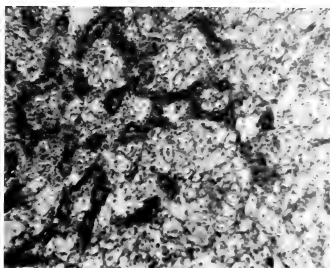


Figure 22

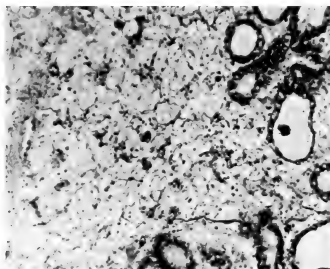


Figure 23

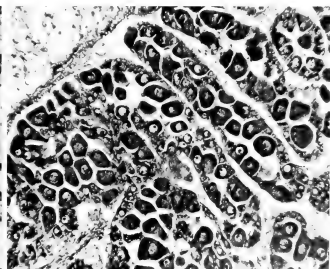


Figure 24

Figure 21: Gonad of Virginia oyster conditioned for 72 days at 15° C. ($\times 125$)

Figure 22: Gonad of South Carolina oyster conditioned for 72 days at 15° C. ($\times 125$)

Figure 23: Gonad of Florida oyster conditioned for 72 days at 15° C. ($\times 125$)

Figure 24: Gonad of Long Island Sound female oyster conditioned for 24 days at 18° C. ($\times 125$)



that the sexes could not be easily distinguished even by microscopic examination of gonadal smears.

The differences in the ability of the oysters of the different groups to ripen at the same temperatures were also clearly demonstrated at a temperature of 15° C. Again, the Long Island Sound oysters ripened comparatively well under this condition, giving about 60% spawners after a conditioning period of 45 days. Even after 72 days of conditioning, however, only 20% of the New Jersey oysters could be recognized as males or females and the majority possessed winter-like gonads. Only a single oyster had some eggs sufficiently developed to be fertilizable. The same condition existed with minor modifications in the Virginia and South Carolina groups, and the Florida oysters were so poorly developed that no definite gonad was detectable in most.

When exposed to a temperature of 18° C the Long Island Sound oysters again stood apart from the other groups. After 21 days of conditioning the majority of these oysters already contained ripe gametes. When these oysters were stimulated by exposure to higher temperature, after only 24 days of conditioning, many spawned. On the other hand, none of the New Jersey group could be induced to spawn after 51 days of conditioning, and even after 71 days of conditioning at 18° C, most of the oysters in this group still contained virtually undifferentiated gonads, even though some could be induced to spawn. The Virginia oysters could not develop ripe gametes after being subjected to 18° C for 71 days. Strangely enough, after the same period of conditioning about 15% of the South Carolina oysters were ripe and could be induced to spawn, although about half of the individuals possessed such undifferentiated gonads that the sex could not be determined.

The ability of a considerable percentage of South Carolina oysters to develop gonads at 18° C, although none of the Virginia group could, interrupted the otherwise orderly progression, from north to south, of the temperature requirements for gonad development of different geographical populations of *Crassostrea virginica*. An explanation for the unexpected behavior of this precocious fraction of the South Carolina population is not available at present. Moreover, these precocious few seem incongruous, considering that about 50% of the group failed to respond to conditioning at 18° C for more than a 2-month period. The possibility is suggested that the South Carolina oysters, even though, according to the sender, collected from the same area, were apparently of different genetic composition and thus resemble the apparent mixture of several distinct genotypes in the oyster population of Long Island Sound (LOOSANOFF, 1965).

Nevertheless, causes other than genetic may be responsible for such differences in the gametogenic activities of the South Carolina oysters.

Obviously, such atypical fractions of the general populations, as in the samples of South Carolina oysters, make it increasingly clear that, in addition to histological and chromatographic studies of the oysters, to which references have already been made, it may be necessary to employ genetic studies to clarify that rather difficult problem. While I was still the director of Milford Laboratory a program for genetic studies of bivalves was established, and at present experiments of this nature are being conducted by Dr. Arlene C. Longwell. According to Dr. Longwell, with whom I corresponded, "There is sufficient justification for the interesting speculation that genetic differences play a role in the differences in gametogenic activities of the South Carolina oysters exposed to the same temperatures which failed to elicit a response from the other southern groups studied."

The design of these experiments may be criticized on the grounds that the differences which I found among the groups of oysters of different regions may be due to the fact that the preconditioning period, extending roughly from the second half of September until the middle of January, was too short to allow the oysters to become acclimated to the new environment. The matter of acclimation in mollusks, which was so ably discussed by SEGAL (1961), is still poorly understood, however. It can probably be considerably clarified by conducting a series of experiments with successive generations of laboratory-reared oysters originating from parents of different geographical areas to determine whether successive generations of these oysters still fail to spawn in Long Island Sound. We had planned a series of these experiments in the past but, unfortunately, a heavy mortality of southern oysters in Milford Harbor during winters (especially Florida seed oysters of which almost 100% died) prevented completion of the research. Nevertheless, our preliminary studies definitely established that oysters that originally came as seed from different geographical regions and spent approximately 2 years in Milford Harbor did not become acclimated even after that long period (LOOSANOFF & NOMEJKO, 1951).

Additional observations of a similar nature were made on 150 New Jersey oysters shipped to me as seed by Dr. Thurlow Nelson in the fall of 1948. These oysters, which came from the Delaware River near Cape May, were attached to *Macra* shells and were easily identifiable. They grew well and during the first winter showed no mortality whatsoever – indeed were the best of the 6 groups with which we were working at that time, excel-

ling even the Long Island Sound oysters which showed a mortality of 9%. In the fall of 1949 the average length of these oysters was 77.7 mm; in the fall of 1950 it was 92.8 mm; and in the late summer of 1951 it exceeded 12 cm. When these large, healthy oysters were examined in the fall of 1951 over 30% still contained nearly undischarged gonads, and many others were in only partially spawned condition. Thus, even after 3 years of existence in Long Island Sound the New Jersey oysters, or at least a large portion of them, were unable to spawn.

Still another evidence of lack of acclimation in oysters, which has already been briefly reported (LOOSANOFF & NOMEJKO, 1951), was found in a large shipment of native oysters from Seaside of Virginia, near Chincoteague. These oysters were planted by F. Mansfield & Sons Company in comparatively shallow water in Long Island Sound south of West Haven. Our observations showed that these Virginia oysters, even after 3 years existence in the new environment, failed to discharge their gonads. These oysters, which, by general appearance and other peculiarities, were easily distinguished from those of Long Island Sound, went into hibernation each fall still retaining all or at least large quantities of undischarged spawn, thus clearly demonstrating that they had not acclimated to the new set of conditions.

One more group of oysters transplanted to Long Island Sound that were unable to discharge their spawn in the new environment was that of several carloads of *Crassostrea virginica* shipped by F. M. Flower & Sons Oyster Company from the lower part of the Hudson River, the area between Hastings-on-Hudson and Tarrytown, and planted near the mouth of the Housatonic River, which enters Long Island Sound near Milford. We examined these oysters for more than 3 years and found that they also went into hibernation with undischarged gonads. This last transplantation is of special interest because it clearly demonstrates that distinctly different oyster populations, as far as their spawning requirements are concerned, may exist comparatively close to each other since the distance between the Housatonic River and the area of the Hudson River from which the oysters came is only about 70 miles.

Perhaps the most striking evidence of the inability of some pelecypods to acclimate to the new conditions was offered by DAVIS (1955). He has shown conclusively in his experiments with *Ostrea lurida* CARPENTER, 1864, that the 6th generation of these oysters transplanted from Puget Sound to Long Island Sound could not survive New England winters, despite some selection, through the death of the most susceptible each year, before the remainder were brought into the laboratory during the coldest period.

We may close this discussion by concluding that there are distinct populations of *Crassostrea virginica* that require different temperature regimes for completion of gametogenesis and spawning. This conclusion is based on the experiments described in this article, which were devoted to studies of the comparative progress of gametogenesis of oysters of different geographical areas kept in Milford Harbor for approximately 3 months and then subjected to conditioning at relatively low temperatures ranging from 12° C to 18° C. These observations support our earlier conclusion (LOOSANOFF & NOMEJKO, 1951) that NELSON's (1928) assumption that the breeding temperature is the same for *Crassostrea virginica* over all parts of its range is incorrect. Moreover, the present experiments clearly indicate the existence of several physiological variants within the general populations of *C. virginica*.

ACKNOWLEDGMENTS

I thank Dr. Harold Haskins of Rutgers University, Dr. Jay Andrews of Virginia Fisheries Laboratory, Dr. G. R. Lunz of Bears Bluff Laboratories, and Dr. Robert Ingle of Tallahassee, Florida, for sending me the samples of oysters from their respective areas; Mr. Harry Davis of the Bureau of Commercial Fisheries Biological Laboratory at Milford, Connecticut, for assisting in some of the studies; Miss Rita Riccia of the same laboratory for her assistance in the preparation of this manuscript, and Mr. Andrew Driscoll of the Pacific Marine Station, for preparing the photo-micrographs. I also thank the National Science Foundation for giving me the opportunity to complete these studies.

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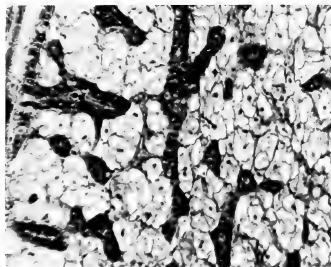


Figure 25

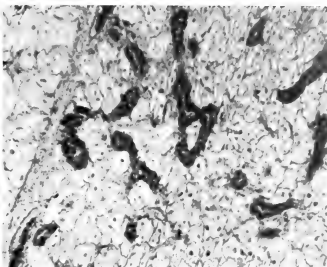


Figure 26

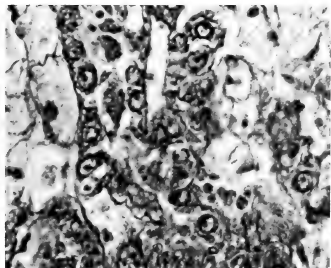


Figure 27

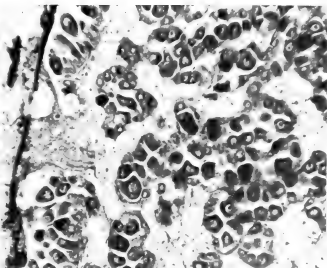


Figure 28

Figure 25: Gonad of New Jersey oyster conditioned for 32 days at 18° C. (× 125)

Figure 26: Gonad of unripe New Jersey oyster conditioned for 71 days at 18° C. (× 125)

Figure 27: Gonad of Virginia oyster conditioned for 71 days at 18° C. (× 125)

Figure 28: Gonad of South Carolina oyster conditioned for 58 days at 18° C. Some ripe eggs were found in this individual. (× 125)



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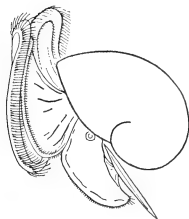
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A Review of the Living Leptonacean Bivalves of the Genus *Aligena*

BY

HAROLD W. HARRY

Texas A&M Marine Laboratory, Galveston, Texas 77550, and Rice University, Houston, Texas 77001

(40 Text figures)

IDENTIFYING A SPECIES OF *Aligena* from Galveston, which proved to be undescribed, led to the present review. I have reappraised all Recent species named in the genus or referred to it. Possibly other species will soon be found to belong here, for many of the descriptions and illustrations of leptonid bivalves in the literature are tantalizingly vague with regards to critical characters of the shell, and their generic allocations are questionable.

I am grateful to Mr. Cornelius Mock and Mr. Charles Guice of the U. S. Bureau of Commercial Fisheries, Galveston, for aid in field work and much useful material. Dr. J. P. E. Morrison, Dr. Harald Rehder and Dr. Joseph Rosewater, as well as the whole staff of the Department of Mollusks of the U. S. National Museum were very generous in aiding my studies there. This study was supported in part by National Science Foundation Grant GB 2753.

Aligena H. C. LEA, 1846

The genus *Aligena* H. C. LEA, 1843, when proposed, contained but two species of fossil bivalves from the Miocene beds of Petersburg, Virginia, *A. striata* and *A. laevis*, both nude names with neither designated as type. LEA described these species in 1846. In his synopsis of the Leptonacea of North America, DALL (1899) designated "*Abra aequata* CONRAD" as type of the genus. The following year he published a monographic account of *Aligena* (DALL, 1900: pp. 1175 - 1177), in which he noted that CONRAD's species was originally named *Amphidesma aequata* CONRAD, 1843, and that this is a senior synonym of *Aligena striata* H. C. LEA, 1846. KELLIOPSS VERRILL & BUSH, 1898, type by monotypy *Montacuta elevata* STIMPSON, 1851, was considered a subjective synonym of *Aligena* by DALL (1899, p. 895; 1890, p. 1175). In this

he is probably justified, for the type species of *Kelliopsis* differs from the type of *Aligena* chiefly in being smaller, more quadrate, and in having weaker sculpturing. I have not had the opportunity to examine specimens of 2 other nominal genera based on Tertiary fossils of Europe, which DALL (1900) cites as congeneric (*Laubriereia* COSSMANN, 1887) or closely related (*Spaniodon* REUSS, 1867).

Several additional living species have been added to *Aligena* in the twentieth century. *Aligena cerritensis* ARNOLD, 1903 was described from a Pleistocene deposit in southern California and has since been found living, chiefly south of there. *Aligena borniana* DALL, 1908 from deep water in the mid-Pacific is dubiously a member of the genus, and *A. pisum* DALL, 1908, from the Strait of Magellan, is generically misplaced. *Aligena cokeri* DALL, 1909 from Peru is a member of the genus, as is *A. nucea* DALL, 1913 from the Gulf of California.

THIELE (1935) noted that *Aligena* differed so slightly from *Montacuta* that he was only doubtfully willing to recognize it as a subgenus therein. He pointed out that most living *Aligena* were on the shores of the American continents, but he also suggested, correctly, that *Montacuta salamensis* JAECKEL & THIELE, 1931 (in THIELE & JAECKEL, 1931) from the east coast of Africa might be an *Aligena*.

Two more species have recently been added to the list from the eastern Pacific, *Aligena redondoensis* T. BURCH, 1941, and *A. borealis* COWAN, 1964. For reasons noted below, these probably belong elsewhere.

The nondescript bivalves which are usually cited in the superfamily Erycinacea or Leptonacea are so poorly known that the allocation of genera to families is a complex question, which cannot yet be fully decided. For the present we may place *Aligena* in the Montacutidae, and define the genus as follows.

DEFINITION OF THE GENUS *Aligena*

Shell equivalve, small, 1 cm or less in maximum dimension; color always uniformly white; shape various, but usually the height and length are about the same; umbos touching, slightly prosogyrous, located midway the length or behind it, or rarely before it. There is no lunule, escutcheon or corcelet. The dorsal margins do not project across the midline. Outer surface sculptured only with growth lines, which may be very faint, or moderately pronounced, regular in size and spacing or irregular in those characters. Adductor scars are about equal in size, subquadrate to suboval; the pedal retractor scars join the adductor muscle scars (or are separated from them slightly, perhaps depending on stage of growth). Pallial line simple, without sinus, joining the ventral end of the adductor muscle scars, usually with ragged margins, at least on the upper side, and often discontinuous in one or several places. Valve margin thin and smooth. Umbonal cavity deep, the hinge plate very narrow, usually with a finger-like tooth below the umbo in each valve, of which the right one is slightly larger than the left. Lateral teeth are always absent. Ligament consisting of a thin, external part (tensilium) on the very margin of the shell following its curvature and extending before and behind the umbos, and a larger, straight, elongate internal part (resilium) which is entirely separated from the tensilium. The resilium extends in a straight line from immediately below the umbos for a moderate distance backward, and is therefore entirely opisthodontic. Its attachments, or resilifers, are usually buttressed by a moderate thickening of the shell, or chondrophore, often terminated behind in a sharp angle. The resilifers diverge outward and downward from the umbos, and thus the resilium is narrow in front, broader behind, with the form of an elongate triangle in ventral view. The ventral surface of the resilium may be calcified, forming a lithodesma. The protoconch is oval, smooth, large (about 0.3 to 0.4 mm long) and remarkably persistent, being plainly evident in most large shells which are not worn. The periostracum is thin or moderately thick, light tan, usually with a smooth outer surface. It is only moderately persistent in most species.

In some species there is a vague, shallow sulcus on the disc of the valve, running from the umbo to the mid-ventral margin, and a corresponding sinus in the latter. Such species are slightly reniform in profile. This sulcus and marginal sinus are found in several other genera of the Leptonacea.

The species of *Aligena* as presently restricted are marine, mostly living from the lower tide level to shallow depths of perhaps 40 fathoms along the temperate and tropical shores chiefly of the American continents. One species of the Indo-Pacific fauna extends to greater depths. None are known from the eastern Atlantic or Antarctic faunas.

Although a few species of Leptonacea may be free living, most seem to be commensal with burrowing invertebrates, chiefly crustacea, polychaete worms and echinoderms. Nothing definite is known about the habits of most species of *Aligena*, but *A. cokeri* and possibly *A. texasiana* are probably polychaete associates.

TYPE SPECIES OF THE GENUS *Aligena*

Aligena aequata (CONRAD, 1843)

(Figures 1, 2, and 3)

Amphidesma aequata CONRAD, 1843. Proc. Acad. Sci. Philadelphia 1:307. Not figured. Type locality: St. Mary's Co., Maryland, and Wilmington, North Carolina. (Miocene)

Aligena striata H. C. LEA, 1846. Trans. Amer. Philosoph. Soc., 2nd Ser. 9: 238; pl. 34, fig. 13. Type locality: Tertiary beds of Petersburg, Virginia. (Miocene, *vide* DALL)

Aligena aequata CONRAD, 1843. DALL, 1900, Trans. Wagner Free Inst. Sci. 3 (5): 1175; pl. 24, figs. 8, 8a, 8b (of vol. 3, no. 4).

The following description is based on a single left valve which is lot No. 144173 of the U. S. N. M. Paleontological Collection. It is labeled "St. Mary's River, Md., Miocene."

Shell subtriangular, dorsal margins only slightly convex, of about equal length, sloping abruptly at about the same angle. Ends and ventral margin evenly rounded. Umbo moderately inflated, protoconch large (but too indistinct to measure), located midway the length of



Figure 1

Aligena aequata CONRAD. Hinge of the specimen, USNM 144173, from the Miocene of Maryland, which Dall studied

the valve, and slightly turned forward. Curvature of the disc even, slightly flattened over the middle, but with no trace of a sulcus, nor any appreciable expansion of the anterior slope. No lunule, escutcheon or corselet. Sculpt-



Figure 2

Interior of valve of same shell as Figure 1. Length 9.93 mm

ture of numerous, closely spaced growth rests, of unequal size, but periodically enlarged to form small concentric ridges. Valve thin for its size, inner margin smooth. Hinge plate narrow, with a single finger-like tooth below the umbo in this, the left valve. The tooth projects well across the midplane. The resilial and tensilial parts of the ligament may have been completely separated, with the latter running along the very margin, where a nymphal roughening is evident. The inner part attached along a resilifer which begins below the umbo, and diverges ventrally and laterally. The chondrophore is very thickened, ending in a rounded point too far from the median plane to be a tooth. Length (extrapolating for the broken end) 9.93 mm; height 8.78 mm; semi-diameter 2.84 mm.

Another lot, U.S.N.M. 112378, labeled "*Aligena aequata* CONRAD from the Pliocene, Waccamaw River, South Carolina", consists of a left and a right valve much

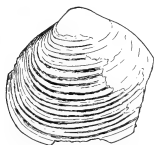


Figure 3

Exterior of valve of same shell as Figure 1

better preserved than the lot from the Maryland locality. These valves are perhaps the ones figured by DALL, 1898, pl. 24, figs. 8, 8a, 8b. The ridges on the specimens are regular, but not quite as strong as he has shown them. They have no differentiated nymphal attachment for the tensilium, and the hinge plate is narrower than that of the valve from the Maryland Miocene.

To evaluate the relationship of *Aligena* to *Montacuta* TURTON, 1822, specimens of *M. substriata* MONTAGU from the Jeffreys collection at the National Museum were studied. This species, originally named *Mya substriata* MONTAGU, 1808, is the type species of *Montacuta* TURTON, 1822 by subsequent designation of GRAY, 1847. I have not seen Montagu's work, but according to FORBES & HANLEY (1850, 2: 77), the species was published in the supplement, which appeared in 1808 (*vide* PALMER, 1958, p. 312).

Montacuta substriata (MONTAGU, 1808)

(Figures 4 to 7)

The shell is minute (2.97 mm long, 2.84 mm high, 0.79 mm semidiameter), thin, obliquely ovate, with the anterior end longer than the posterior. The umbos are scarcely inflated, touching, and essentially orthogyrus. The protoconch is persistent, small and oval (0.125 mm long). Equivalve, with the disc moderately and regularly inflated, somewhat polished, with a few widely spaced



Figure 4

Montacuta substriata (MONTAGU). A specimen from Zetland in the Jeffreys collection (USNM 170517). Length 2.97 mm

growth rests. Major sculpture is of 3 to 10 widely spaced, faint radial lines, slightly elevated, most prominent on the middle third of the disk and toward the ventral margin. Valve margin smooth and sharp; pallial line wide, without a sinus and with even margins, joining the

adductor muscle scars at their lower ends. Adductor scars about equal in size, irregularly elongate, and with dorsal projections which are probably the scars of the pedal retractor muscles. Hinge short, with a single tooth in each valve. The teeth are rounded, elongated ridges beginning under the umbos and extending forward. That of the right valve is larger, and the tooth at the left

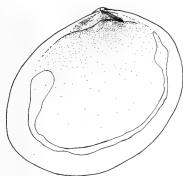


Figure 5

Interior of same valve as in Figure 4

valve fits in a shallow, poorly defined socket in front of and above the right one. A tensilial part of the ligament, if present, must be small and without noticeable attachment on the shell. The resilium is a flat ribbon, its attachments beginning at the umbo and sloping downward and laterally. The mid-ventral part of the resilium is a calcified strip.

Thus, the resilium is very similar to that of *Aligena*, which it also resembles in lacking lateral teeth, lunule and escutcheon. But these negative characters are outweighed by the differences between this species and *Aligena aequata*: *Montacuta substriata* is a much smaller shell, with small protoconch and umbos orthogyrous rather

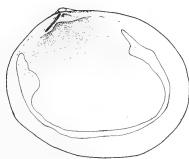


Figure 6

Interior of left valve of same shell shown in Figure 4

than prosogyrous. Growth striae are so poorly developed that the surface appears polished, whereas all species included in *Aligena* as here defined and limited, have moderate to prominent growth striae, giving the shell a silky texture, or even expanded to form concentric ribs. The pallial line in *Montacuta* is smooth and continuous, but the dorsal margin is ragged in all species of *Aligena* in which I have been able to study it. The radial sculpture of *Montacuta* is lacking in *Aligena*, and there is no finger-like projection of the teeth which are nearly always present in *Aligena*.

Another species of the eastern Atlantic generally included in *Montacuta*, *M. ferruginosa* (MONTAGU, 1808), has finger-like cardinal teeth projecting normal to the median plane of the shell, as well as low lamelliform bases of these teeth, continuing forward along the hinge plate. This may be why THIELE (1935) included *Aligena* in *Montacuta*. *Montacuta ferruginosa* is an elongate shell, with smooth surface, smooth margined pallial line, small size and orthogyrous protoconch, thus showing similarities to *M. substriata*. Its resilium is somewhat shorter than in *M. substriata*, the attachments diverging downward and outward more abruptly, so that it approaches the transverse ligament of *Mysella*. The differences in anatomy of the soft parts between *Montacuta substriata*



Figure 7

Ventral view of the hinge line of a shell of *Montacuta substriata* from the same lot as Figure 4, which had been fortuitously broken in such a way that the interlocking of the teeth and the resilium, with lithodesma, can be seen

and *M. ferruginosa* as detailed by OLDFIELD (1961) are, when considered in conjunction with differences in the shell, sufficient to suggest that the two species may ultimately be placed in different genera.

The loss of teeth may be a secondary character within the leptonid bivalves, which has occurred several times independently. At least one true *Aligena*, *A. cokeri*, is consistently edentate. We may suppose that ancestral populations may have had true lateral teeth (i.e. no projections of one valve margin below the other) and a cardinal tooth in each valve which had an elongated base extending forward under the hinge margin, with a digitiform projection normal to it at its umbonal end. The lateral teeth were lost in some later populations (including *Montacuta* and *Aligena*), the digitiform process lost in

M. substriata (but retained in *M. ferruginosa*), the elongate base lost in most *Aligena*, but not *A. cokeri* and *A. (?) borniana*.

Montacuta substriata and *M. ferruginosa* are the only two species recognized in that genus by WINCKWORTH (1932) in his list of British Marine Mollusca. A third species was included with doubt. According to FORBES & HANLEY (1850), *M. ferruginosa* is known only from British seas, and lives subtidally to at least 30 fathoms. *Montacuta substriata* was known to them from Britain and Scandinavia, but not southward. They report it from depths of 5 to 140 fathoms. OLDFIELD (1961) gave an extensive anatomical account of both species, and noted that they are commensals on sea urchins. Insofar as comparison is possible, there are few significant differences in the anatomy of the soft parts of *M. substriata* and *Aligena texasiana* (see below).

SPECIES OF THE WESTERN ATLANTIC

Aligena elevata (STIMPSON, 1851)

(Figures 8 and 9)

Montacuta bidentata "TURTON 1822" of GOULD, 1841, Invert. Mass. Ed. 1, p. 59, not of TURTON (whose species is *Mya bidentata* MONTAGU, 1803, now placed in *Myella*).

Montacuta elevata STIMPSON, 1851. Shells of New England, p. 16 (merely renamed the species misidentified by GOULD).

Kelliopsis elevata STIMPSON, 1851. VERRILL & BUSH, 1898, Proc. U. S. Nat. Mus., 20: 784; pl. 93, figs. 2-4; pl. 94, figs. 7, 8.

Aligena elevata STIMPSON, 1851. DALL, 1899, Proc. U. S. Nat. Mus. 21: 879, 884; 1900, Trans. Wagner Free Inst. Sci., 3 (5): 1177.

The shell is small (length 5.84 mm, height 4.75 mm, diameter 3.34 mm), equivalve, moderately inflated, oval to subtriangular, with the umbos moderately prominent, slightly closer to the hind end, and distinctly prosogyrous. The dorsal and ventral margins are only slightly convex, the front and hind margins more strongly rounded. The disc is evenly convex, with no median sulcus. Sculpture of fine, somewhat irregular growth lines, giving the shell a silky texture. There is a very thin, light tan periostracum. The protoconch is oval, about 0.4 mm long.

The hinge line is narrow, with a prominent finger-like cardinal tooth, projecting normal to the median plane. The resilifer is typical of the genus, and a tensilium attaches to the very margin of the shell over it. The dorsal margin of the broad, simple pallial line is ragged.

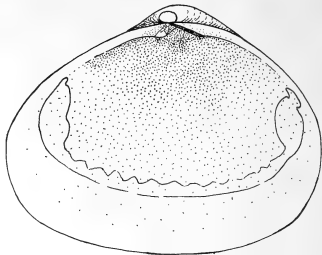


Figure 8

Aligena elevata (STIMPSON), interior of a right valve from Chelsea Beach, Massachusetts (USNM 159288). Length 5.81 mm

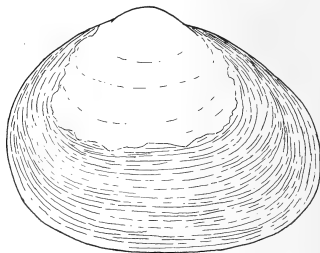


Figure 9

Exterior of same valve as Figure 8

This species is represented in the National collection from 16 lots ranging from Massachusetts to Long Island, from the shore to 10 fathoms.

Aligena texasiana HARRY, spec. nov.

(Figures 10 to 14)

Shell small (length 4.81 mm, height 3.75 mm, diameter 2.50 mm), white, chalky, moderately inflated; equivalve, sculptured only with numerous, irregularly spaced, fine

growth lines. Subtriangular to suboval or subquadrate, almost equilateral, the beaks being slightly closer to the hind end, but distinctly turned forward. The dorsal margins are very slightly convex, the hind one somewhat shorter than the front one. Both the front and hind ends of the shell are evenly rounded, and of nearly the same

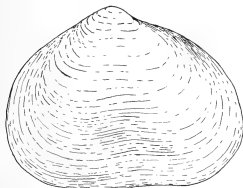


Figure 10

Aligena texasiana HARRY, spec. nov. Holotype. Length 4.81 mm

convexity. They continue as a smooth curve into the ventral margin, which is almost straight, but shows a slight sinus midway its length, at the end of the sulcus. The region of the disc between the umbo and antero-ventral part of the margin is somewhat more inflated than the rest of the disc. From the umbo to the middle of the ventral margin is a shallow, vague sulcus, only prominent on the lower half of larger shells. The protoconch is prominent, oval, about 0.348 mm in diameter.

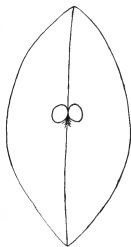


Figure 11

Aligena texasiana HARRY, spec. nov. Holotype

The umbos touch, and there is no lunule or escutcheon. The valves are thin, with smooth inner surfaces and margins. Adductor scars are prominent, suboval, and about equal in size. Retractor scars are adjacent or confluent (depending on growth) with them dorsally. The pallial line is prominent, without sinus, and broken into a series of subtriangular marks probably representing discrete muscle bundles. The resilium is flattened, short, attached by its long edges to each valve, along a slight ridge just under the dorsal valve margins and behind the umbos. The resilial attachments descend and diverge posteriorly. The medial third of the ventral surface of the resilium is calcified along its axis. There is a single tooth in each valve, rounded and projecting slightly forward across the midline. The one in the right valve is larger, and passes in front of the left tooth. A thin, light tan periostracum on fresh shells gives them a satiny luster.

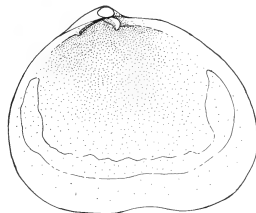


Figure 12

Aligena texasiana HARRY, spec. nov. Paratype, Length 5.13 mm

Type Locality: East end of West Bay, Galveston, Texas. The holotype is USNM no. 679103. This species has been found only in West Bay and Lower Galveston Bay at Galveston. It was not found in more than 60 samples ranging from 3 to 18 fathoms offshore. Within the bays, it occurs from the lowest tide level to 7 feet, which is about the deepest water of the bays, outside of the passes and dredged channels. It seems to be only local within the bays, and is not common. Frequently polychaetes are abundant in the samples containing it, suggesting it may have some mutualistic relationship with them, but details are lacking. It also occurs with *Mysella planulata*, with which it is easily confused. The latter is more flattened, has opisthogyrous umbos with a smaller protoconch, and is without a sulcus on the disc. PARKER (1959, pp. 2128-

2129) evidently confused them, labeling a figure of *Aligena texasiana* with the name "*Mysella planulata*" (l. c., figs. 21a, 21b). His specimens were from bays farther south on the Texas coast, but no exact localities are indicated. This species also occurs in Barataria Bay, Louisiana, where I recorded it as *Aligena* sp. (HARRY, 1942).

From *Aligena elevata*, this species differs in being generally smaller, more inflated, and with a median sulcus on the disc. *Aligena texasiana* is perhaps closest to what I have called *A. nucea* DALL from the west coast of Mexico, but the latter is not as inflated and the sulcus is less prominent. The Texas species is smaller than *A. cokeri*, with the sculpture and sulcus not as prominent, and cardinal teeth seem always to be present.

ANATOMICAL NOTES

In the laboratory, *Aligena texasiana* is moderately active, extending the foot and pulling its body, resting on its side, up to it. It crawls up the vertical wall of the glass dish, and up large shell fragments, attaching itself very loosely by a minute byssal thread or two. In the active animal, the siphonal opening is not evident, and my study did not extend to the direction of water currents. The mantle margin is exposed along the edge of the shell only to show a row of minute, closely spaced papillae, scarcely longer than their diameter, uniformly distributed along the edge of both mantle lobes between the adductor muscles.

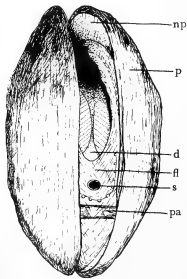


Figure 13

Aligena texasiana HARRY. Postventral view of an animal from which the shell has been decalcified

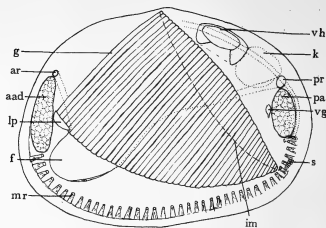


Figure 14

Aligena texasiana HARRY, spec. nov.

Diagram of the superficial anatomy of a specimen from which the shell has been removed

Symbols used in Figures 13 and 14:

- aad anterior adductor muscle
- ar anterior pedal retractor muscle
- d diaphragm
- f foot
- fl fused lamellae of mantle margin
- g gill
- im dorsal margin of ascending gill lamella
- k kidney
- lp labial palp
- mr retractor muscle of mantle margin
- np nascent periostracum
- p periostracum
- pa posterior adductor muscle
- pr posterior pedal retractor muscle
- s siphonal opening (excurrent)
- vg visceral ganglion
- vh ventricle of the heart

The flesh of the living animal internally is snow white, except that the liver is colored light brown, and the kidney is faint tan. A byssal gland is not evident in the living animal, but there is a groove along the keeled ventral margin of the foot. The foot is somewhat finger-shaped, although short and rounded when retracted.

Studies on specimens preserved in 70% isopropyl alcohol were made after the shell was dissolved in a very weak hydrochloric acid (2%) solution in alcohol of 70% strength. The outer, or true, periostracum is thin, transparent, light tan colored, with a roughened outer surface in harmony with the growth ridges of the shell. The free edge of this layer of periostracum is held firmly in the periostracal groove between the outer and middle lamellae of the mantle margin. Since the latter has re-

tracted some distance from the shell margin, there is an abrupt turning of the outer periostracal sheet, along the line of the shell margin, and a wide strip of nascent periostracum between it and the mantle margin.

An inner periostracal sheet seems to adhere closely to the outer surface of the mantle in specimens deshelled in acid, but it was probably separated from the mantle by the innermost layer of calcareous material, the hypostracum. I therefore propose for this sheet of periostracum the name *mesostracum*. In *Aligena texasiana* it is smooth, tough, pliable, thin, and very faint tan colored. It seems to extend to the very margin of the mantle.

The margins of the two mantle lobes are fused for a short distance below the posterior adductor muscle. The fusion is in the form of a thin, transverse sheet, with a large round hole at its upper end. This hole has a smooth margin and is the excurrent siphonal opening. The papillae extend along the sides of the sheet, and the two rows of them join above the siphonal opening.

The mantle margin is thickened, but the rest of the mantle is very thin, almost transparent. Discrete bundles of retractor muscles can be seen in it, extending upward for a short distance, and originating on the valves of the shell along the pallial line.

The gills are represented only by a single huge subtriangular demibranch on each side. There is no muscular suspensory septum. Each demibranch has about 50 filaments, the longest being anterior, and the others shortening in length progressively toward the hind end. The lamellae are not pleated. They are eulamellibranchian, with firm inter-filamentary junctions orderly arranged horizontally to give the gill a latticed appearance (not shown in Figure 14). The free margins of the demibranchs are grooved. The anterior filament of each is attached along the visceral mass throughout its length. The ascending lamellae are somewhat narrower than the outer, descending ones. They attach along the visceral mass in the front part of the gill, and behind it to each other. The hind tips of the gills do not reach quite to the siphonal opening, but there is a triangular, horizontal sheet of tissue extending from the hind tip of the gills to the fusion of the mantle lobes just below the opening. Thus, the mantle cavity is completely separated into incurrent and excurrent chambers by a structurally complete diaphragm.

The labial palps are minute triangles, which overlap only the first few filaments of the gill. The ventricle of the heart surrounds the rectum, the kidney is between the pericardium and the posterior adductor muscle.

No internal detail of the viscera has been determined. On the surface of the visceral mass, there were a few low projections, which could as easily be interpreted as

phenomena of contraction rather than as projections of the liver and gonads. The latter condition has been described in other leptonids (OLDFIELD, 1961).

A specimen collected in early spring had several hundred early embryos in the gills, but there was no evidence of embryos in specimens examined in June and July. OLDFIELD (*op. cit.*) describes a sequential shift in sexuality of some British leptonids.

SPECIES OF THE EASTERN PACIFIC

Aligena cerritensis ARNOLD, 1903

(Figures 15 to 17)

Aligena cerritensis ARNOLD, 1903. Mem. Calif. Acad. Sci. 3: 138; pl. 13, fig. 3. Type locality: Los Cerritos (Signal Hill) near Long Beach, Los Angeles County, California. (Pleistocene)

The following description is based on the holotype USNM 162529, a single right valve (Figure 15).

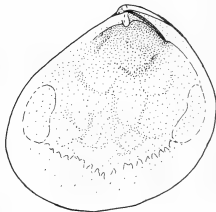


Figure 15

Aligena cerritensis ARNOLD.

Holotype, USNM 162529. Length 9.03 mm

Shell large for the genus (length 9.03 mm, height 8.39 mm, semidiameter 2.58 mm), obliquely ovoid, the posterior dorsal margin sloping downward at a greater angle with the horizontal than the anterior dorsal one. The shell is unusually thick, and the inside of the disc, above the pallial line, has an irregular surface. The chevron-shaped origins of the pallial retractor muscle give the upper part of the pallial line an irregular appearance. These are actually engraved on the thickening of the disc. The adductor scars seem to be large and slightly kidney-

shaped. The resilifer is as in *Aligena*, and the shell ridge along it is large. There is a single, finger-like tooth in front of the ligament in this, the right valve, projecting normal to the midplane and across it. Outer surface slightly flattened over the middle of the disc, smooth, with only a few irregular growth rests on the lower third of the shell. No lunule or escutcheon.

This species is living on the coast of Lower California and on the mainland opposite. Some of the 14 lots of



Figure 16

Aligena cerritensis ARNOLD

A Recent shell from "off Lower Calif." USNM 212588 to show the steep slope of the postdorsal margin. Length 5.63 mm

this species in the National Museum have depth data, showing it occurs in from $\frac{1}{2}$ to 5 fathoms, and in fine grey or black sand. It may occur with *Aligena nucea*. Fresh shells are rarely as thickened as the holotype. They often have a periostracum which is much thicker than on any other species of *Aligena*, and which may persist only over the lower third of the shell. It is brownish grey in

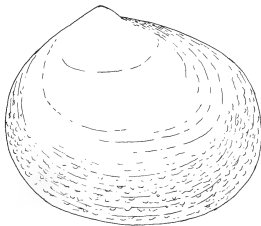


Figure 17

Aligena cerritensis ARNOLD

A Recent shell from Magdalena Bay, Lower California (USNM 217809) showing papillate periostracum over lower third of valve. Length 5.00 mm

some shells, light tan on others, and usually has small triangular projections from its surface. Figure 17 is drawn from a Recent shell having such a cuticle. The protoconch is large. The shape is variable, and small shells are difficult to separate from *A. nucea*. The beak cavities are not as deep as in that species, there is never a sulcus on the disc, and the ventral margin is always slightly convex, never having a sinus. The umbos are always well toward the hind end of the shell.

Aligena obliqua HARRY, spec. nov.

(Figures 18 to 20)

Shell small (length 6.19 mm; height 6.19 mm, at right angle to length; diameter 2.38 mm; protoconch oval, 0.284 mm long), white, covered with a light tan, very thin periostracum. Moderately and regularly inflated, obliquely oval, with the margins evenly rounded. Equivalve, inequilateral, with the umbos about a third of the

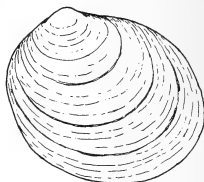


Figure 18

Aligena obliqua HARRY, spec. nov.

Holotype, USNM 532795. Length 6.19 mm

length from the hind end. Umbos only moderately inflated, turned slightly forward, touching, with persistent protoconchs. No lunule or escutcheon. Sculptured only with growth striae, faint, close together, and mostly regular, with occasional (3 on holotype) growth rests more prominently defined. The growth striae give the surface a silky texture. Valves of moderate and even thickness, margin smooth and sharp, adductor muscle scars very elongate oval, with the foot retractor scars confluent with their dorsal ends. Beak cavities deep, hinge very narrow. A single prominent finger-like tooth arises just in front of the umbo in each valve, projecting well across the midline. The tooth of the right valve is larger than that

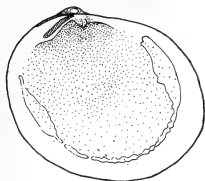


Figure 19

Aligena obliqua HARRY, spec. nov.
Holotype, interior of valve

of the left, more directly under the umbo, and it passes behind the left when the valves are joined. Ligament with a thin, external part on the very margin of the shell, and of the same length as the resilial part. The latter begins under the umbo, its attachment slopes downward and laterally, for not quite half the distance from the umbo to the top of the posterior adductor scar. The ventral surface of the resilium is strongly calcified. The shell is thickened slightly along the resilial attachment.

Holotype, USNM no. 532795, is from Bacochibampo Bay, Sonora, Mexico (Orcutt). This lot also contains 2 paratypes with joined valves and 10 disjoined valves. All are in fresh condition, showing little evidence of weathering.

The distinctive shape of this species easily separates it from the other 3 living on the west coast. It is very similar

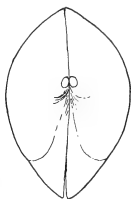


Figure 20

Aligena obliqua HARRY, spec. nov.

Dorsal view of a paratype from same lot as that of Figure 18

to *Aligena minor* DALL (1900, p. 1177, pl. 44, fig. 8), a Miocene species from North Carolina, which differs chiefly in being smaller, and not as oblique.

The National Museum has 6 lots of this species, from Guaymas (Sonora) and Mazatlan (Sinaloa) on the main-coast of the Gulf of California. Depths are indicated on the labels as $\frac{1}{2}$ to $1\frac{1}{2}$ fathoms, and substrate type of medium-coarse grey sand.

Aligena nucea DALL, 1913

(Figures 21 to 24)

Aligena nucea DALL, 1913. Proc. U.S. Nat. Mus., 45: 597.

Not figured. Type locality: Gulf of California. BURCH, 1941, Nautilus 55: pl. 4, fig. 3 (photograph of holotype). OLSSON, 1961. Panamic-Pacific Pelecypoda, p. 234; pl.

The single left valve, which is the holotype of this species (USNM no. 267149), is probably a more extreme variant of the populations which I think constitute this species than is ordinarily found in populations of *Aligena*. A description of the holotype (Figure 21) is as follows:



Figure 21

Aligena nucea DALL. Holotype, USNM 267149. Length 3.88 mm

Shell small (length 3.88 mm, height 3.19 mm, semidiameter 1.31 mm), the umbo is very slightly behind the midpoint of the length, slightly prosogyrous, and evidently touched the one opposite. Protoconch large, persistent



Figure 22

Aligena nucea DALL. Dorsal view of holotype

but indistinct. Resilifer typical of *Aligena*, but unusually large and prominent. There is a single finger-like tooth just in front of the umbo. Sculpture of growth lines only, more prominent on the lower third of the valve. Disc



Figure 23

Aligena nucua DALL. Interior of valve from Concepcion Bay, Gulf of California (USNM 558735). Length 5.63 mm

curvature uniform, with no flattening or sulcus. Ventral margin evenly rounded, with the post-ventral part slightly flattened. No lunule or escutcheon.

It differs from *Aligena cerritensis* of the same length in having a more swollen umbo, which is more centrally placed. *Aligena obliqua* of this size is already markedly oblique. From *A. cokeri* it differs in being dentate. Several lots of specimens have accumulated in the National Museum since Dall named this species, which, though poorly represented by the holotype, seem nonetheless to be conspecific with it.

Figures 23 and 24 are drawn from a valve of USNM 558735 from Concepcion Bay, Gulf of California. The shell is about equally rounded at both ends, with the ventral margin flattened, or more often with a slight sinus in the middle. There is usually a vague, very shallow and broad sulcus on the lower half of the middle of larger valves, and the anterior slope of the disc sometimes is slightly inflated. The texture is silky, formed by very fine, closely spaced and somewhat irregular growth lines. The cardinal tooth is always present. The umbos vary in position, may be slightly in front or slightly behind the midpoint of the length.



Figure 24

Aligena nucua DALL. Exterior of same valve as in Figure 23

Eleven lots of this species at the National Museum are all from the Gulf of California, with depths indicated as 1 to 7 fathoms, and substrate as fine grey or black sand. OLSSON (1961) notes it extends south to Nicaragua.

Aligena cokeri DALL, 1909

(Figures 25, 26)

Aligena cokeri DALL, 1909. Proc. U. S. Nat. Mus. 37: 155-156; pl. 28, figs. 5, 6. Type locality: "Attached to worm tubes thrown upon the beach of the lagoon at Capon, Peru." OLSSON, 1961. Panamic-Pacific Pelecypoda, p. 234; pl. 33, figs. 6, 6a, 6b.

Shell small (Holotype, USNM 207759, length 7.74 mm, height 6.45 mm, diameter 5.68 mm), very inflated, ends of about equal curvature, rounded, ventral margin only slightly curved, and with a rounded shallow notch in the middle, where the sulcus ends. Beaks strongly prosogyrous, slightly in front of the midpoint of the length. Protoconch persistent and large (about 0.38 mm long, slightly oval). A vaguely defined, moderately wide furrow runs from the umbo to the midpoint of the ventral margin, is

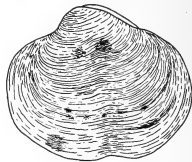


Figure 25

Aligena cokeri DALL. Holotype, USNM 207759. Length 7.74 mm

scarcely evident on the umbones, becomes more pronounced on the lower $\frac{2}{3}$ of the shell. Growth lines very prominent, standing up as small, sharp ridges, but somewhat irregular, though closely spaced; the shells tend to be peculiarly malcolated in some places, with vague, irregular depressions and elevations. In other lots than the type, the growth-line sculpture may be very regular or nearly absent, and the depressions and elevations absent, or variously prominent. In some specimens from the northern part of the range, the growth lines are absent, the bumps and hollows so pronounced and numerous that one might almost proclaim it a different species, were there no connecting intergrades. The form may become

subtriangular in these, and the sulcus on the disc be absent. The resilifer is typical of the genus; in some paratype shells with both valves connected, a tensilium is evident, but this is scarcely more than a slight thickening of the periostracum, joining the valves over the resilium. The finger-like tooth of *Aligena* is absent in this species,

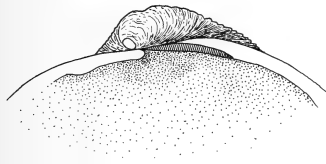


Figure 26

Aligena cokeri DALL. Hinge of right valve of a syntype

which has a slight, rounded ridge running forward from the umbos along the hinge. The ridge of the left valve is smaller than that of the right one. Neither ridge projects across the median plane.

The edentulous condition was noted by DALL (1909) and OLSSON (1961, pl. 33, fig. 6) has illustrated it with a good photograph.

Besides the type lot, there are several others at the National Museum ranging from the Gulf of California to Panama. Some labels indicate depths of 1 to 4 fathoms.

SPECIES OF THE WESTERN PACIFIC AND INDIAN OCEANS

Aligena salamensis (JAECKEL & THIELE, 1931)

(Figures 27 to 29)

Montacuta salamensis JAECKEL & THIELE, 1931. Wiss. Ergeb. d. deutsch. Tiefsee-Expedit. 21 (1): 226; pl. 4, fig. 98.
Type locality: Dar es Salam, 50 meters deep.

THIELE (1935) noted that this species from the coast of East Africa might belong to *Aligena*. Several lots in the National Museum from southeastern Asia seem to fit it, insofar as comparison with the meager description and figure of JAECKEL & THIELE (in THIELE & JAECKEL, 1931) allow comparison.

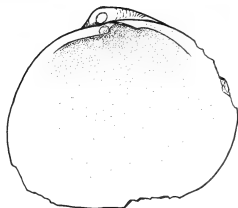


Figure 27

Aligena salamensis JAECKEL & THIELE.
China Sea, 230 fathoms, off Pratas Island. USNM 297075.
Length 9.42 mm

Shell small (length 9.42 mm, height 8.39 mm, semidiameter 3.57 mm), very inflated, subquadrate in profile, with margins evenly rounded. Beaks about midway the length, turned forward, touching, the protoconch oval, large, smooth, and persistent. Ventral margin slightly sinuous, where the sulcus of the disc meets it. The sulcus is prominent only over the lower half of larger shells, and the anterior slope of the shell is slightly more inflated than the rest of the disc. Sculpture of closely placed growth lines of uniform size, which become coarser on the lower half of the shell.

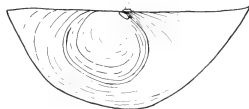


Figure 28

Aligena salamensis JAECKEL & THIELE.
Dorsal view of valve drawn in Figure 29

Valve thin, margin smooth and sharp. The hinge has a large fingerform tooth projecting below the umbo; the resilial attachment slopes downward and outward from the umbo, and is buttressed by a thickening of the shell along it, ending in a prominent angle at the hind end of the resilium.

Young specimens are evenly inflated and almost circular. They lack a median sulcus, and might be thought another species, were it not for connecting intergrades. The National Museum has 4 lots from the China Seas, off Pratas Island, ranging from 88 to 230 fathoms, and 7 lots from the Philippines, ranging from 10 to 37 fathoms. A

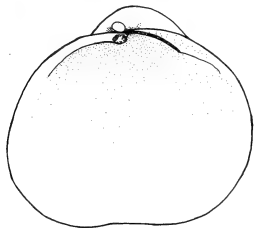


Figure 29

Aligena salamensis JAECKEL & THIELE.

A valve from 32 fathoms S. E. of Bantayan Island, Philippines (USNM 293038). Length 4.69 mm. This was drawn at twice the magnification of Figure 27

single lot from the Buton Strait, Celebes, is from 37 fathoms also. Most lots have only one or two valves, the maximum being six. All of the smaller shells are from the greater depths, but there are sufficient intergrades to demonstrate they are conspecific with the larger ones. These were collected in 1909 by the research vessel "Albatross."

This species seems to penetrate to greater depths than others in the genus, but its shell is very characteristic of *Aligena* in all respects.

SPECIES INCERTIS SEDIS

Aligena (?) *borniana* DALL, 1908

(Figures 30, 31)

Aligena borniana DALL, 1908. Bull. Mus. Comp. Zool. 43 (6): 413; pl. 10, fig. 2. Type locality: Pacific Ocean, 16°32' S latitude, 119°59' W longitude, 2012 fathoms.

Shell large for the genus (length 14.2 mm, height 10.3 mm, semidiameter 3.6 mm; protoconch oval, about 0.44 mm long), elongate oval, the front and hind margins evenly



Figure 30

Aligena (?) *borniana* DALL. Holotype, USNM 110585. Length 14.2 mm

rounded and of nearly the same arc, the ventral margin almost straight. Valves inflated, of the same size, beaks about $\frac{1}{3}$ the length from the hind end, prosogyrous and touching each other.

Very closely spaced growth lines and a light tan periostracum give the outer surface a silky texture. Growth lines are more prominent near the beaks than elsewhere. No lunule or escutcheon, but there is a narrow, vaguely defined sulcus on the posterior slope on the upper third of the shell only. The middle of the disc is slightly flattened, but shows no trace of a sulcus (contrary to Dall's description). No evidence of a tensilium on the disjoined

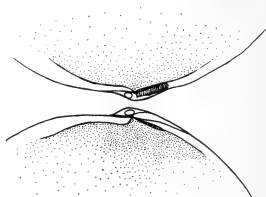


Figure 31

Aligena (?) *borniana* DALL. Hinge of holotype with resilium attached to left valve

valves of the single available specimen, the holotype. The resilium is typical of *Aligena*, but seems not to have a calcified strip. The hinge line in front of the umbo is slightly thickened, more so in the right than in the left valve, but there is no finger-like projection, and neither thickening extends across the midplane. The adductor scars and pallial line could not be distinguished.

The relatively compressed appearance of this species, its large size, the faint sulcus on the posterior slope, as well as the great depth at which it occurs, are characters which, if relatively insignificant, argue against this species being an *Aligena*. The lack of a projecting tooth typical of most species of *Aligena* is not significant, since *A. cokeri* has no such tooth. This might be placed in *Montacuta*, except for the large size and the faint posterior sulcus. The latter suggests a corcelet, and thus the Thyasiridae, but the shape is unlike that group.

SPECIES REMOVED FROM *Aligena*

Three species have been described as *Aligena* which belong elsewhere. Two of these are probably Thyasiridae: *Aligena redondoensis* T. BURCH, 1941 and *A. pisum* DALL, 1908. The third, *A. borealis* COWAN, 1962 may belong to that family. The three are sufficiently distinct from each other to merit being placed in separate genera.

The smaller species of Thyasiridae may be covered with iron encrustation, a character which has not been found in *Aligena*, although it is known to occur in *Montacuta ferruginosa* (see OLDFIELD, 1961). The thyasirids, at least the smaller ones, are generally found at greater depths than most species of *Aligena*, and occur in cooler waters when living in shallow depths. A lunule, escutcheon and corcelet (see CARTER, 1967, for a discussion of these characters) may occur in various combinations and manifest to varying degrees in the Thyasiridae, but they are absent in *Aligena*.

Axinulus VERRILL & BUSH, 1898

Axinulus (?) *pisum* (DALL, 1908)

(Figures 32, 33)

Aligena pisum DALL, 1908. Bull. Mus. Comp. Zool. 43 (6): 413. Not figured. Type locality: "Magellan Strait, in 61 fathoms."

Only the holotype of this species, a slightly worn left valve, is known. In a large series at the National Museum of unidentified shells dredged near the Philippines by the "*Albatross*," there are a few valves which are very similar,

if not identical (USNM 300962, Lagonoy, G., E. Luzon, Philippines, 569 fms.). The following description is based on the holotype.

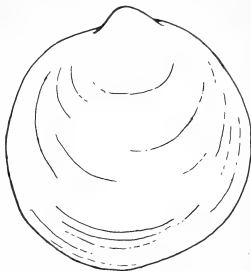


Figure 32

Axinulus (?) *pisum* DALL.

Holotype, USNM 110715. Length 2.43 mm

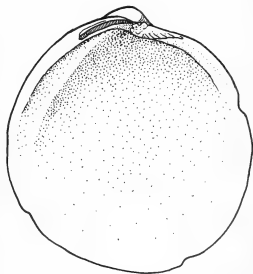


Figure 33

Axinulus (?) *pisum* DALL. Holotype, interior view

Shell small (length 2.43 mm, height 2.69 mm, semi-diameter 0.82 mm), subcircular, white and opaque with a very light tan, thin periostracum to which no dirt is adhering. Umbo moderately inflated, and slightly proso-

gyrous. The protoconch is scarcely evident, but seems to be slightly oval, about 0.156 mm long. The curvature of the disc is regular, with no lunule, escutcheon, or corcelet evident externally. Surface almost smooth, showing only a few very faint growth rests. The valve is thin, its edge smooth. Adductor scars and pallial line not evident. There is a faint but distinct ridge, ill-defined but fairly broad, extending from the umbonal cavity near the posterior dorsal margin, very suggestive of a corcelet. Hinge plate narrow, with no evidence of a tensilium, but with a resilifer beginning just under the umbo and sloping downward and outward for a moderate length. A single irregular tooth is immediately below and in front of the umbo. The hind part of the tooth may be a broken, finger-like projection, but it appears to have several rounded bosses, one of which is on the top side. A triangular extension forward of this tooth has a moderately sharp ventral border, along which are several incised lines sloping upward and backward.

Tomburchus HARRY, gen. nov. in Thyasiridae

Type Species: *Aligena redondoensis* T. BURCH, 1941.

Shells small, oval, equivalve, inequilateral, with the umbos nearer the hind end, and prosogyrous. An escutcheon is well defined by a sharp angle on the posterior slope, extending from the umbo to the hind end of the shell. No lateral teeth, but the postdorsal slope of the left valve extends under the margin of the right one. The left valve margin is also deflected under and just before the umbo, as a tooth-like lamella with bifid margin, passing under a small, rounded, tooth-like extension of the margin of the right valve. Ligament superficial, but covered by a turned up margin of the shell, extending along the adumbonal half of the escutcheon. The genus is named in honor of Dr. Tom Burch, of a family whose several members have greatly stimulated and furthered the study of malacology.

Tomburchus redondoensis (T. BURCH, 1941)

(Figures 34 to 37)

Aligena redondoensis T. BURCH, 1941. Nautilus 55: 50-51; pl. 4, figs. 5, 6, 7. Type locality: 75 fathoms off Redondo Beach, California, about latitude 33°38'50" W, longitude 118°26'30" N.

The paratypes of this species cited by T. BURCH (1941) as sent to the National Museum were misplaced and unavailable to me when I studied *Aligena* there in 1968. Two lots of the National collection identified by Dr. A.

M. Keen and cited by T. Burch were studied instead. One of these, USNM 211882 (48 fms., off Santa Rosa Id., Calif.) has only a single very worn valve, but is possibly this species. The other, USNM 331216a (129 fms., off La Jolla, Calif.), has two specimens which fit very closely the figures and description of *Aligena redondoensis*. The following description is based on that lot.

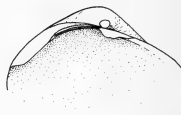


Figure 34

Tomburchus redondoensis (T. BURCH)
From 128 fathoms "off La Jolla, Calif." (USNM 331216a).
Hinge of left valve. Length 3.10 mm

Shell small (length 3.10 mm, height 2.53 mm, semidiameter 1.14 mm), oval, equivalve, inequilateral, with the umbos slightly closer to the hind end, moderately inflated and prosogyrous. Protoconch persistent, oval, about 0.158 mm long. Valves white, moderately inflated, sculptured only by fine growth lines, with a thin periostracum to which mud and iron deposits adhere tenaciously in a few places. The margin of the shell is formed by one continuous curve, somewhat more flattened anterodorsally and along the ventral margin, but closed by the more flattened segment of the postdorsal margin, which meets the ventral margin in a rounded angle, about halfway between the top and the bottom of the shell.



Figure 35

Tomburchus redondoensis (T. BURCH)
Top view of same valve as in Figure 34. The dashed line is the limit of the postdorsal margin inserted below that of the right valve

No lunule is differentiated. A narrow, lenticular escutcheon is well defined by a sharp margin and deeply excavated surface, which is pinched up into a keel along the umbonal half of the shell margin. There is no corcelet. The ligament seems to consist of one piece, with the tensilium and resilium possibly fused. It is about $\frac{1}{3}$ as

long as the escutcheon, and attached to the inner side of the pinched up part of the shell margins. It is effectively concealed by this keel. There are no lateral teeth as such, but in the left valve the posterior half of the dorsal margin within the escutcheon is extended across the me-

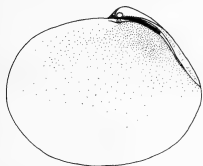


Figure 36

Tomburchus redondoensis (T. BURCH)
Right valve of same shell as in Figure 34

dian plane, and bent slightly downward. It fits under the margin of the right valve, which does not cross the median plane there. The margin of the left valve is also extended just before and under the umbo, as a flattened, bifid tooth. Seen from above, this "tooth" is narrow, elongate along the shell margin, with its free margin smoothly rounded. In the right valve there is a small, hemispherical extension of the shell margin, which does



Figure 37

Tomburchus redondoensis (T. BURCH)
Top view of a shell with valves joined, from same lot as Figure 34.
Darkened areas are detritus

not extend across the median plane, but fits in the notch of the tooth of the left valve. The adductor scars and pallial line could not be studied.

A few lots of unidentified shells at the National Museum, dredged near the Philippines by the "Albatross" in 1909, evidently are this species or a closely related one, but

the present study could not be extended to include them. Another member of *Tomburchus* may be *Axinus dubius* DAUTZENBERG & FISCHER, 1897 (10: 215 - 216, pl. 6, figs. 18 to 21; renamed *Thyasira dubia* (DAUTZENBERG & FISCHER by DAUTZENBERG, 1927: 312 - 313, pl. 8, figs. 35 to 38) from the Azores, but I have seen no authentic specimens.

"*Lucina*" *ferruginosa* FORBES, 1843, as described and figured by FORBES & HANLEY (1850, 2: 60 - 62, pl. 34, fig. 1) from Britain may also be of this genus. WINCKWORTH (1932, p. 242) puts FORBES' species in *Thyasira*. VERRILL & BUSH (1898, p. 793, pl. 87, figs. 7, 8) cite what may be the same species as "*Cryptodon* (*Axinulus*) *ferruginosus* (FORBES)", but they give no description and the figure has insufficient detail.

Odontogena COWAN, 1964

Odontogena borealis (COWAN, 1964)

(Figures 38 to 40)

Aligena (*Odontogena*) *borealis* COWAN, 1964. Veliger 7 (2): 108 - 109; pl. 20, figs. 1, 2. Type locality: Georgia Strait, British Columbia, Canada, 190 fathoms.

The following description is based on the single paratype, disjoined valves of one shell, which is USNM 657130.

Shell small (length 2.56 mm, height 2.37 mm, semi-diameter 0.63 mm), subcircular, resembling a minute *Lucina*, with slightly convex, long post-dorsal margin. The moderately convex shorter anterior margin meets the umbo in such a way as to give the dorsal margin a notched appearance. No lunule, escutcheon or corcelet. Inflated, and covered with a ferruginous deposit which had been mostly removed, to show a faint tan surface of silky texture with a few irregular growth lines as the only

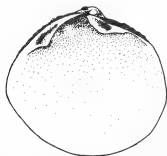


Figure 38

Odontogena borealis (COWAN). Paratype, USNM 657130
Length 2.56 mm

sculpture. Beaks touching, slightly turned forward, about midway the length of the shell. Valves thin, the margin acute and smooth. Adductor scars and pallial line could not be made out. Hinge line very narrow, poorly manifest; ligament entirely internal, elongate, flattened, attached along its side to the valves, beginning at the umbos and extending a short distance behind; the attachments do not diverge posteriorly. Teeth two in each valve; these

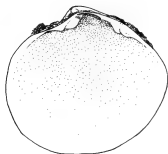


Figure 39

Odontogena borealis (COWAN).

Right valve of same shell as in Figure 38

are large masses, poorly defined, as are the sockets into which they fit. One tooth in each valve is just under and in front of the umbo, the other is behind the ligament. Those in the right valve are bifid and receive in the vague groove thus formed a short rounded projection from the teeth of the left valve. The ligament does not appear to have a calcareous midstrip, but this could be a matter of age.

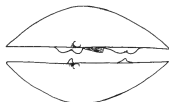


Figure 40

Odontogena borealis (COWAN).

Top view of shell in Figures 38 and 39

This species resembles *Aligena* of the east coast in type of ligament, general shape, texture and size of shell, and absence of lunule and escutcheon. The type of teeth, however, removes it from that genus, as characters in this group go, and the subgenus Cowan erected for it may be used unless an earlier name is found.

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The Egg Capsules of *Jenneria pustulata* (LIGHTFOOT, 1786) with Notes on Spawning in the Laboratory

BY

CHARLES N. D'ASARO

Institute of Marine Sciences, University of Miami¹, Miami, Florida 33149

(1 Text figure; 1 Table)

INTRODUCTION

Jenneria pustulata (LIGHTFOOT, 1786) is a brightly colored cypracean distributed in shallow water from the southern end of the Gulf of California to Ecuador (KEEN, 1958). It is a hardy species normally found in association with the stony corals upon which it feeds. The relationship of the species to other members of the superfamily is not well established. KEEN (*op. cit.*) believes the shape of the radular teeth and other anatomical characters can be homologized with those of *Trivia*; however, SCHILDER (1936) places *J. pustulata* in the Oculidae (Amphiperatidae). Data on the structure of the egg capsule and the larval stages can add to the understanding of phylogeny in this species.

METHODS

Adult specimens of *Jenneria pustulata* were collected by Dr. F.M. Bayer of the Institute of Marine Sciences, University of Miami, from Venado Island in the Bay of Panama in August, 1965. Of this material, a pair (female 18 mm, male 13 mm) were transported alive to the Institute, where they were maintained for three years. The specimens were kept in an aquarium with running sea water at ambient temperatures. Assorted coelenterates were also kept in the same aquarium. Stony corals, including *Porites* sp., *Phyllangia americana* MILNE-EDWARDS & HAINE, 1850 and *Siderastrea siderea* ELLIS & SOLANDER, 1786 were used as food. There was a marked preference for *Phyllangia* over the other species; however, all were eventually accepted. During the period of observation, which extended from January, 1967 to May,

1968, the animals were not disturbed and had a constant supply of food.

The egg capsules and embryos were preserved in 10% sea water formalin. All drawings were made from preserved material with the aid of a camera lucida.

BREEDING HABITS

Spawning began when the water temperature exceeded 24° C for 3 to 4 weeks (Table 1). The breeding season at Miami extended from April to December. During this period, 20 egg masses were produced. The number of capsules deposited per spawning ranged from 14 to 233 with an average of 125. A total of 2495 capsules was produced. Copulation took place from about 4 days to minutes prior to the beginning of spawning. The female moved onto the walls of the aquarium away from the sediment before beginning to spawn. No capsules were found on the corals. During the annual period, this process was repeated approximately twice a month.

Before selecting a site for oviposition, the female examines the walls of the aquarium for several hours. After selection, an area slightly larger than the diameter of a capsule is cleaned of periphyton and other surface deposits by the radula for about 8 minutes. Then the propodium is folded over the cleared area, and a capsule is passed from the oviduct down a ciliated groove on the right side. Transport involves about one minute. The propodial muscles knead the capsule while it is held in place. Glandular cells secrete a layer of adhesive which imparts the final shape. Cleaning begins again about 2 minutes before the capsule is completely attached. The whole cycle involves approximately 20 minutes. At this rate to produce the larger egg masses, oviposition must continue for at least 3 days. Brooding, as noted among related cypraceans by ØSTERGAARD (1950), does not occur.

¹ Contribution No. 955 from the Institute of Marine Sciences, University of Miami. This investigation was conducted under the auspices of the U.S. Public Health Service (GM-125-41-02).

Table 1

The Spawning of *Jenneria pustulata* at Miami, Florida

Date	Number of Capsules per Mass	Bay Temperature (°C)
January, 1967	0	21.5 ¹
February	0	21.5 ¹
March	0	22.0 ¹
April	—	25.0 ¹
April 26	120	26.5
April 30	14	25.0
May 21	145	28.0
May 31	101	28.5
June 19	72	28.0
June 26	85	30.0
July 4	50 ²	29.5
July 7	81 ²	29.0
July 20	99 ²	30.0
July 22	64 ²	30.0
July 28	79	30.5
August 7	192	29.0
September 3	169	30.0
September 18	111	29.5
September 25	110	29.0
October 22	205	25.5
October 27	211	26.5
November 9	233	25.0
November 20	202	24.0
December 5	152	23.0
January 1968	0	21.5 ¹
February	0	20.0 ¹
March	0	21.5 ¹
April	—	24.5 ¹
April	179	26.0

¹ = average; ² = communal mass; ³ = communal mass

There is some indication that communal spawning takes place in the natural habitat. In two instances, the parent returned to an egg mass several days after the initial spawning to deposit capsules (Table 1). In areas with dense populations, it is possible that several females will use the same mass. Communal structures can be identified during development by noting that the contents of the older oothecae have a uniformly darker pigment.

THE EGG MASS

Each cluster of oothecae forms a very irregular oval with a long dimension varying between 5 mm and 30 mm. The pustulate capsules are always placed in a single layer. When overlapping between adjacent structures occurs, only a small portion of the edge of each is in-

volved (Figures 1 a, 1 b). The escape aperture is never covered. Placement of the oothecae in the mass does not vary. The side with the aperture is always placed between 2 capsules in a preceding row. The arrangement of the capsules in long arcs reflects the movements of the parent during spawning.

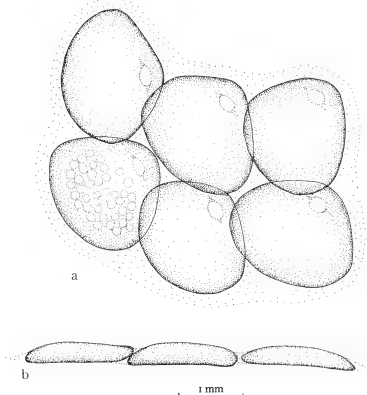


Figure 1

The Egg Capsules of *Jenneria pustulata*

a: dorsal view of 6 capsules from a typical egg mass. One capsule contains embryos.

b: lateral view of 3 capsules.

Oothecae of *Jenneria pustulata* are transparent, colorless, pustulate structures which are somewhat variable in shape. The basal outline of each capsule is roughly the shape of an obtuse triangle with rounded angles (Figure 1 a). Occasional capsules, ovate or round in outline, are the result of the parent's ability to mold the capsules into a compact mass. An oval suture in the membranes of the upper surface close to the obtuse angle marks the escape aperture. Indistinct sutures extending laterally from the aperture reflect the bilobed structure of the oviduct (FRETTER & GRAHAM, 1962). The average dimensions of the capsules are: length - 2.3 mm; width - 1.7 mm; and height - 0.5 mm. Individual oothecae

contain from 65 to 107 embryos and average about 90. The number of embryos per mass varied between 1 200 and 21 000 with an average of 11 200. The total seasonal production for the female was 224 500 embryos.

Development is indirect, with the formation of a long-term planktotrophic veliger. The pinkish-brown pigment which appears in the capsules after about 4 days is the result of the development of a pigmented protoconch. Hatching begins after 13 or 14 days and is completed in 24 to 72 hours.

DISCUSSION

The egg masses of cypraeaceans have general characters which are very uniform within a given genus; however, in some families (as presented by KEEN, 1958) considerable variation does occur. These variations are reconciled in part by suggestions to separate the groups with an echinospira larva (see FRETTER & GRAHAM, 1962). A number of cypraeids were examined by LO BIANCO (1899), VAYSSIÈRE (1927), and ØSTERGAARD (1950). A survey of these investigations and personal observations on the spawn of *Cypraea spurca acicularis* Gmelin, 1791, *C. cervus* LINNAEUS, 1771, and *C. zebra* LINNAEUS, 1758, have shown that the structure of the egg capsules in this family is very uniform. As noted by ØSTERGAARD (*op. cit.*), brood protection is also a characteristic of the family. *Erronea erronea* (LINNAEUS, 1758) (NATARAJAN, 1958) has a layered egg cluster quite similar to that of *Cypraea* and also exhibits brood protection. The capsules of *Trivia arctica* (MONTAGU, 1803) and *T. monacha* (DA COSTA, 1778), which were studied by LEBOUR (1932 a), differ greatly from those of their suggested close relative, *Jenneria pustulata*, in that they are vasiform and are imbedded individually in compound ascidians. Both species have a characteristic echinospira which does not occur in *J. pustulata*. In the Ovulidae, however, *Simnia patula* (PENNANT, 1777) (LEBOUR, 1932 b) has pustulate capsules arranged in a single layer like *J. pustulata*. Similar structure and placement is also found in another ovulid,

Cyphoma gibbosum (LINNAEUS, 1758) (personal observation).

In conclusion, it can be stated that the structural arrangement and placement of capsules by *Jenneria pustulata* is most similar to the processes occurring in the Ovulidae and that a close relationship is implied.

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The Taxonomic Significance and Theoretical Origin of Surface Patterns on a Newly Discovered Bivalve Shell Layer, the Mosaicostracum

BY

GEORGE H. HAMILTON

Department of Paleobiology, Division of Invertebrate Paleontology, Smithsonian Institution
Washington, D. C. 20560

(Plates 26 to 38)

INTRODUCTION

THE STRUCTURE OF BIVALVE SHELLS has been studied with the light microscope at magnifications which allow for a point resolution of 0.2 micron. However, structures present in the shell which are consistent at the species level have not been resolved. The body of knowledge gained so far through use of the light microscope has shown that shell structure is taxonomically consistent to varying degrees at the ordinal level (NEWELL, 1965) and in some cases (i. e. Ostreidae) at generic through familial levels (GUNTER, 1950; CARPENTER, 1848; OBERLING, 1955, 1964; BOGGILD, 1930).

The two major advantages that the electron microscope technique offers are resolutions in the 10 Å range and replicas that permit observation of finely structured surfaces. Electron microscopic examination and an understanding of calcification in the bivalve shell is still in preliminary phases. The body of knowledge is quite large but only a few of the major problems have been resolved regarding the mechanism of crystal growth and related organic components. Significant new discoveries and concepts of shell formation are still being made. An understanding of the genetic control of the mode and product of calcification may furnish valuable new tools to biology and paleontology in the fields of systematics, ecology, phylogeny and evolution.

Electron microscopic examination of the calcified outer surface in fossil and living bivalve shells has resulted in significant new discoveries concerning bivalve shell structure. These potentially have an important bearing on taxonomy and the interpretation of phylogenetic relationships.

A discrete, previously unknown calcareous layer, the *mosaicostracum* (Plates 26 to 38), between the ecto-

stracum and periostracum of numerous, if not all Bivalvia, and at least in some gastropods, has been defined and studied in detail on the Tellinidae. In this family, the *mosaicostracum* is unique in that it displays patterns which are easily recognized and are definitive for each species (Plates 26 to 35). The most cursory examination of areas extraneous of the *mosaicostracum* shows many additional features of the shell useful in species recognition and possibly new approaches to taxonomic description based on shell structure. In view of the large amount of data that has been obtained, this study is restricted to the *mosaicostracum* for the present inasmuch as it is apparently the most useful of the valve structures for taxonomic and phylogenetic studies. Other structures were observed in the ectostracum and mesostracum and will be considered in subsequent studies.

Species recognition from the shell, whether it be whole or fragmented, presents a basic problem to the paleontologist and neontologist. The main purpose of this study is to examine the possibilities of species determination based on electronmicroscopic shell structures and to establish control for the investigation of similar shell structures on fossil bivalves. Preliminary investigations indicate the preservation of the *mosaicostracum* in bivalves at least as old as the Late Cretaceous (Campanian).

This study establishes a technique whereby the malacologist and paleontologist engaged in the study of bivalves can solve problems inherent in the macromorphological approach to taxonomy with the additional information gained by observations with the electron microscope at the ultramicromorphological level. The *mosaicostracum* and the whole study of microstructure adds a potent new tool to the systematic and phylogenetic study of the Bivalvia.

With the application of modern technology to classical problems in systematics some limit will emerge at which the evidence for species identification is reached. Those faunal elements which form mineralized components have given the systematist a most useful device to decipher the intricate code of evolution. If these mineralized components are studied at the ultramicro-morphological level, then the limit of investigation should be the smallest set of organized structures that consistently, at the species level, can aid in a rigorous evaluation of patterns useful to the systematist. The patterns found on the mosaicostracum fit into this realm of evidence.

ACKNOWLEDGMENTS

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Explanation of Plate 26

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 1: *Tellina (Tellina) radiata* LINNAEUS, 1758;
USNM No. 598232

Figure 2: *Tellina (Moerella) salmonea* (CARPENTER, 1864)
USNM No. 108639

Explanation of Plate 27

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 3: *Tellina (Laciolina) laevigata* LINNAEUS, 1758
USNM No. 83334

Figure 4: *Tellina (Laciolina) magna* SPENGLER, 1798
USNM No. 36174

METHODS

The mosaicostracum was detected when replicas of the outer shell surface of *Brachidontes recurvus* (RAFINESQUE, 1820) were being examined in an attempt to isolate the area of the valve where calcite exists. Initial observations of the outer surface revealed a type of calcification that was not continuous with the underlying shell structures. The nonconformity with the underlying ectostracum and the unique appearance of this layer incited further studies on other species of the family Mytilidae. It appeared that a systematic study of the layer may have implications on the problems of interpreting shell structure as well as a possible tool for the recognition of shell structure differences at the species level.

The family Tellinidae was chosen for a systematic study of the patterns on the mosaicostracum for the following reasons:

1. They are well represented in Recent and fossil bivalve assemblages.
2. They have world-wide distribution. Many species have broad geographic ranges spanning several biogeographic provinces.
3. They are euryhaline, have a depth tolerance from the littoral zone to hundreds of feet and inhabit numerous marine environments (YONGE, 1949).
4. Large, relatively complete collections are in the Smithsonian Institution. These had been utilized in a recent revision of the Tellinidae by Dr. K. J. Boss, Harvard University, and could therefore be relied upon to be taxonomically up-to-date and in good order. Boss's systematics were employed in this study.
5. The species are infaunal and are commonly well preserved in the fossil record. The Tellinidae are therefore a group useful to the geologist in interpreting

Explanation of Plate 28

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 5: *Tellina (Phyllodina) squamifera* DESHAYES, 1855
USNM No. 461776

Figure 6: *Tellina (Phyllodina) persica* DALL & SIMPSON, 1901
USNM No. 161780

Explanation of Plate 29

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 7: *Tellina (Merisica) cristallina* SPENGLER, 1798
USNM No. 530395

Figure 8: *Tellina (Merisica) aequistriata* SAY, 1824
USNM No. 194658

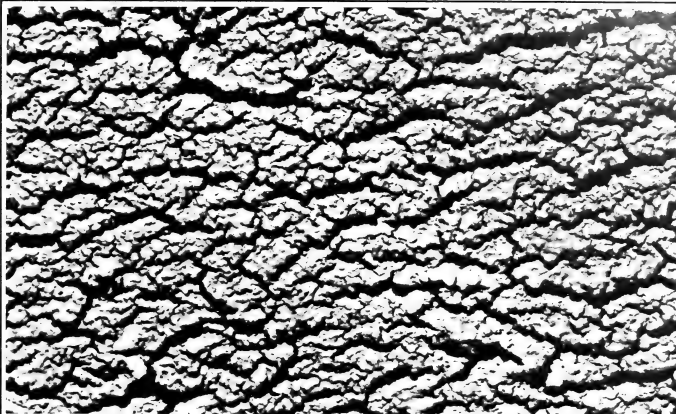


Figure 1



Figure 2





Figure 3

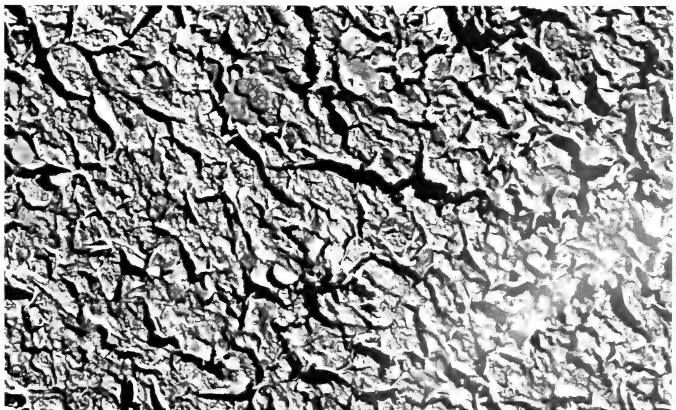


Figure 4



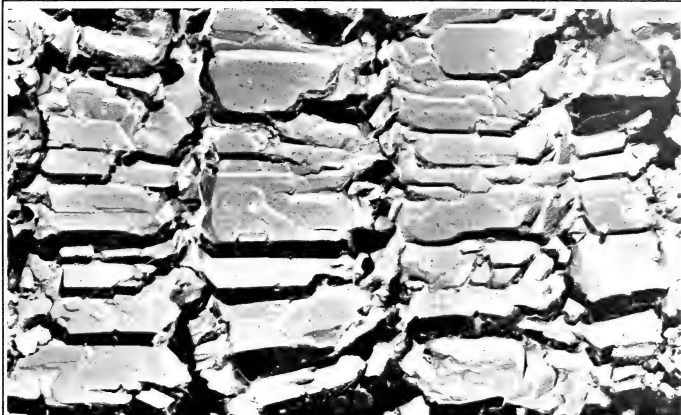


Figure 5

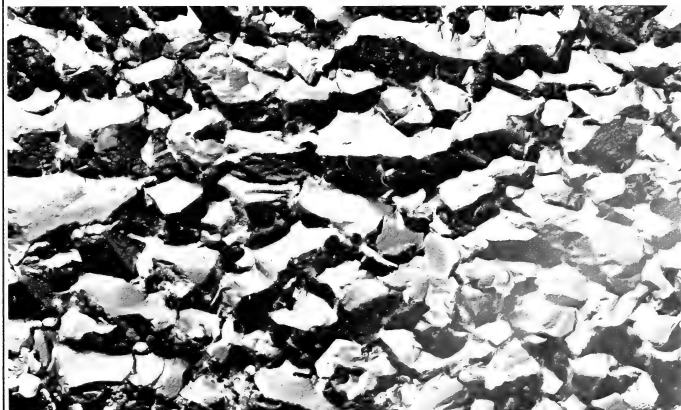


Figure 6



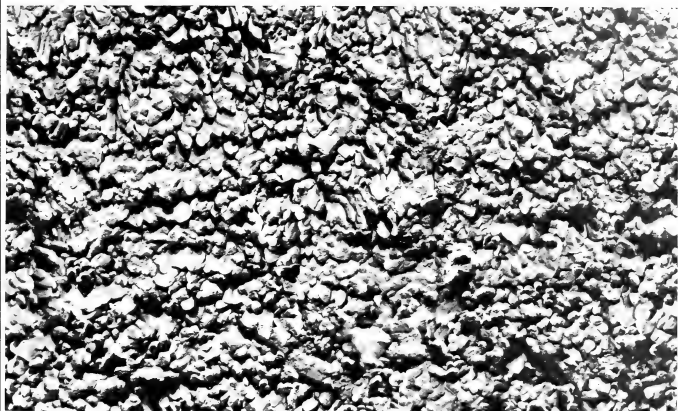


Figure 7

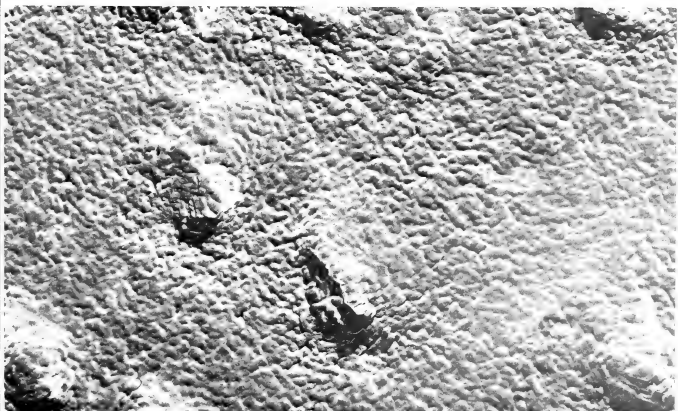


Figure 8



the species-substrate relationships not only from the paleoecologic point of view but also for correlation of ancient sediments.

The specimens of Recent Tellinidae studied were obtained from the United States National Museum, Division of Mollusks collection. Fossils from USNM Department of Paleobiology were classified according to the recent work of Dr. K. J. Boss. The technique was basically that of Dr. K. M. Towe with modifications (Towe & Cifelli, 1967).

The specimens were soaked in a 5% solution of sodium hypochlorite for 30 to 60 days to remove the periostracum and an organic layer covering the mosaicostracum. The organic layer on different species required varying periods of time to dissolve. The smaller species were treated whole and the larger species were cored with an 0.25 inch diamond circular saw. The cores were treated separately from the whole shell. This technique prevented the complete destruction of the shell which could then be returned to the collection. The smaller species were crushed between two pieces of lens tissue while the cores were either broken in half or used whole. Following the bleach treatment the specimens were rinsed and sonicated in de-ionized water, dried at room temperature and shadowed with carbon and platinum simultaneously at an angle of 45°. The coated specimens were decalcified in Na EDTA at a pH of 7.5 and rinsed for 30 minutes in HCl and NaClO with intermediate rinses in distilled water. The cleaned replicas, supported on copper grids covered with a parlodion film, were examined with an RCA EMU 2D electron microscope. The initial magnification of the micrographs was 2500 diameters which were recorded on 2×10 glass lantern slide plates and developed in Microdol-X to produce a fine-grained image. The micrographs were reversed and dodged onto Kodak Fine Grain Positive film with a Log Etronics contact printer in the full dodge position and then photographically enlarged 6 diameters to give a final magnification of 15 000 diameters. A comparison of the patterns at magnifications of less than and more than 15 000 diameters proved unsatisfactory. Judgment as to optimum enlargement was determined by a comparison of the structures that form the patterns. Observation of the shell surface patterns was always executed at this magnification so that an objective evaluation could be made of the information on each specimen.

Some of the smaller species could be replicated whole so that the entire surface of the valve was examined in the microscope without breaking up the continuity of the patterns over the surface. The replicas made from the cores were broken up into two or three pieces and then examined separately. No difference could be detected be-

tween replicas made from the cores or the crushed specimens.

DESCRIPTION OF THE MOSAICOSTRACUM

The mosaicostracum, a calcareous veneer having an average thickness of 0.3μ , is defined as a layer between the periostracum and the ectostracum (Plate 36) and is continuous over the entire outer surface of the valve of bivalve mollusks. The thickness of this layer is uniform and apparently reflects the microscopic surface of the underlying ectostracum. This relief can be observed on some species (Plate 29, Figure 8; Plate 35, Figure 19). The remaining structures which can be seen only with the electron microscope form the most important features of the mosaicostracum and are unique to this layer. They are of the order of 0.5μ and less in size, generally. Species of the family Tellinidae have megascopic shell surface architectures ranging from very smooth to one of coarse concentric ridges. However, the mosaicostracum is continuous over the most pronounced ornamentation (Plate 36). Examination of replicas made of the entire surface of the valve confirms this situation for all of the species studied. There are variations in the distribution of the patterns, or the mosaicostracum may be lacking as a result of abrasion or minor defects due to handling of the specimens prior to this study (see Plate 38). The mosaicostracum may be obscured by the occurrence of random features such as larger than average crystals or organic material insoluble in the bleach.

From the features of the mosaicostracum it is possible to group the patterns into major categories: crystalline, pustular, linear, mosaic, and planar.

Crystalline: Surface displays structures with geometric forms recognized as elements of crystal morphology which can be coarse, medium or fine (Plate 28, Figure 6).

Pustular: Blisterlike elevations of coarse, medium or fine pustules which may or may not have a crystalline appearance (Plate 29, Figure 8).

Linear: Basically linear elements superimposed on a pustular, crystalline or planar surface (Plate 35, Figure 19).

Mosaic: Planar surface broken by incisions or anastomosing sutures and grooves (Plate 30, Figure 10).

Planar: Basically flat surface with a generally smooth appearance (Plate 32, Figure 13).

A definitive description of each category with the inclusion of variations resulting from a compounding of smaller features will necessarily imply that there are

similarities between patterns. The categories are based on observations of the mosaicostracum at 15 000 diameters. Differences in magnification would change the information available for interpretation and thereby alter the position of the pattern in the categories. These categories are tentative, proposed here only as an aid to illustrate the differences between patterns. Future studies will undoubtedly expose new categories.

In order to preserve the simplicity of approach to species recognition by observation of the patterns a description will not be made of each species pattern. They are illustrated on Plates 26 to 35. The difference between patterns of species in the same subgenus is apparent, for example, in Plates 26 to 31, 33, and 35. In some rare instances the difference between patterns of species is subtle and an observation of greater areas of the shell surface is necessary before the pattern for the particular species can be recognized. Experience has shown that an absolute minimum of 3 separate valves or valve fragments of each species must be examined before confidence of new pattern recognition is achieved. Decisions were made on those patterns that appeared dominant or unique. An evaluation of the percent distribution of the pattern indicative of each species over the surface of the valve is shown in Table 1. This evaluation was made from examination of the entire outer surface of smaller valves of each species. Those species with patterns exhibited on less than 50% of the mosaicostracum show other structures which are helpful in species identification but do not fit into any recognizable systematic relation at the present time. Future studies may prove these structures to be of greater use.

THEORY OF THE ORIGIN OF THE MOSAICOSTRACUM

The scheme for the formation of the mineralized components in the invertebrates, especially those having carbonate hard parts, is not fully understood and no known system of reactions can express even the simplest of

structures that occur. There is a general consensus that 2 phases are present in the formation of the mineral components of the skeletal material: the mineral or inorganic phase and the organic phase. The mineral phase, which in the Tellinidae can be restricted to CaCO_3 , is formed in conjunction with various responses of the organism either to a time sequenced mechanism such as circadian cell activity or cell sequences of some shorter period, or to changing conditions of the environment not only of the immediate area of the zone of mineralization but also to an interaction of the organism with the gross environment (ORTON, 1928). There is the possibility that the metabolism of the bivalve reflects the catabolism and assimilation of food with a correlation in shell structures (FOX & COE, 1943). The rate of growth of the valve has been shown to be related to salinity and temperature (MALONE & DODD, 1967). Probably the most significant influence on the type of CaCO_3 formed is the presence of organic material (KITANO & HOOD, 1965). It is on this last point that the theory of the origin of the mosaicostracum is based.

The role of the mantle tissue in the secretion of the various layers of the shell has been investigated and the secretion of the periostracum by the inner epithelium of the outer mantle lobe has been confirmed (BEDHAM, 1958; BEVELANDER & NAKAHARA, 1967). The formation of the mosaicostracum occurs after secretion of the periostracum and prior to secretion of the ectostracum and is related to calcification either on or in an organic substrate forming the innermost surface of the periostracum and the outermost surface of the ectostracum. The composition of this organic substrate is not known but it is within the bounds of the present theory that it is some combination of protein and carbohydrate. If the protein is recognized as being the active compound and the carbohydrate as the passive compound a reasonable relation between the two in terms of their role in the formation of shell material can be visualized. The source of both compounds is the mantle. Within each mantle cell there is the necessary machinery to synthesize proteins and their synthesis is dependent on the proper stimulus from the

Explanation of Plate 30

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15\,000$

Figure 9: *Tellina (Merica) martinicensis* D'ORIGNY, 1842
USNM No. 42897

Figure 10: *Tellina (Eurytellina) angulosa* Gmelin, 1791
USNM No. 33749

Explanation of Plate 31

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15\,000$

Figure 11: *Tellina (Eurytellina) alternata* (SAY, 1822)
USNM No. 40536

Figure 12: *Tellina (Eurytellina) punicea* BORN, 1778
USNM No. 122226

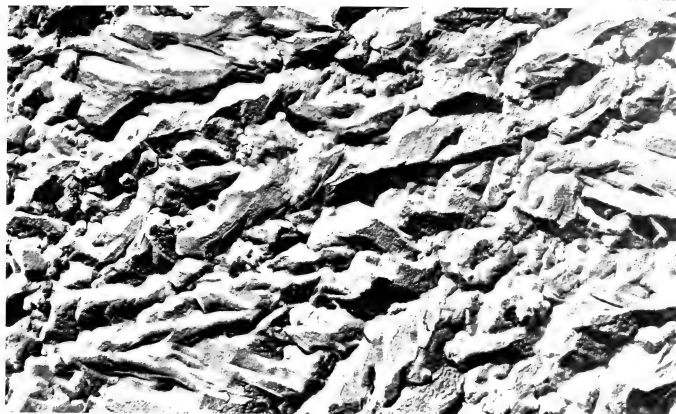


Figure 9

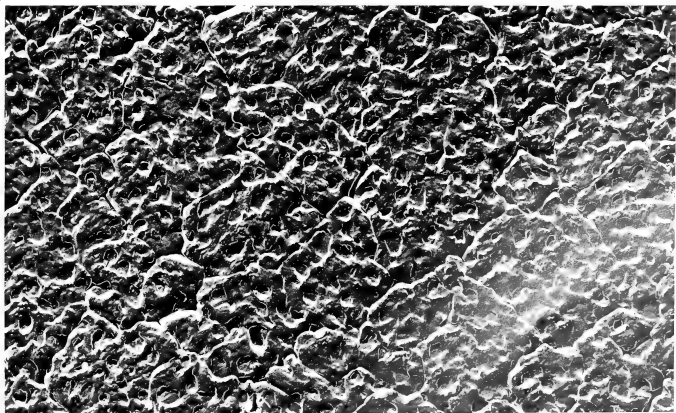


Figure 10



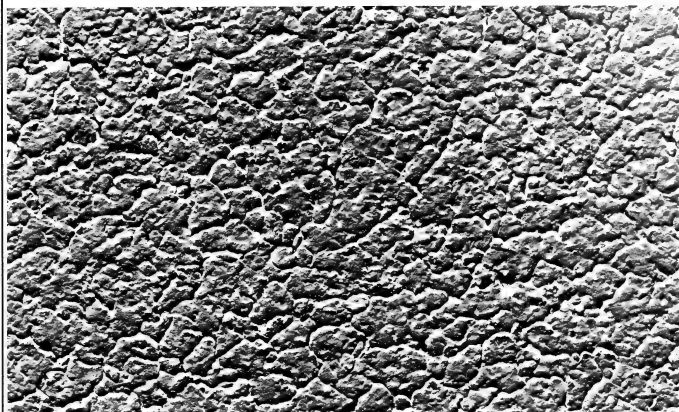


Figure 11

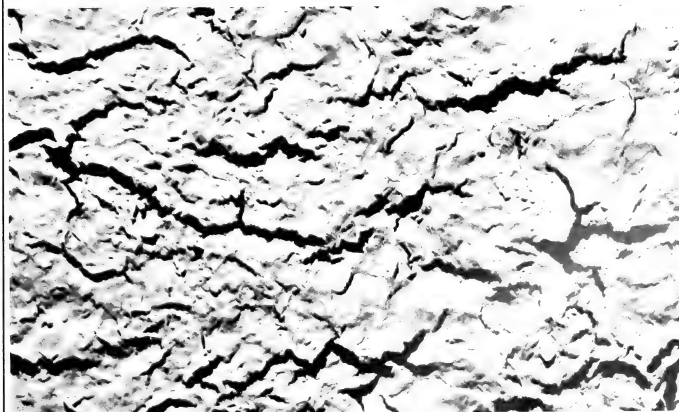


Figure 12



cell nucleus by the DNA. The synthesis of proteins is not completely understood, so only a brief outline will be given on which to base a particular aspect of the theory.

The cytoplasm of the cells making up the mantle-epithelia contains ribosomes which are a combination of RNA and protein. These ribosomes are utilized in the synthesis of proteins when they react to messenger RNA which is patterned after the DNA. When the proper or specific information is transferred from the DNA by the RNA to the ribosome, individual amino acids are assimilated in some sequence to form a chain-like structure or protein. The protein separates from the ribosome and assumes some role in the organism. It is important to bear in mind that the DNA contains the genetic information. Although many types of protein are produced in the cell, some of these (if not just one) are instrumental in the calcification process in the shell and have certain genetic properties reflected in their structure. We could consider these properties as being the smallest unit of species indication where species are based on the shell characteristics. The protein is then secreted from the mantle and arrives at the shell surface or, as is the case with the mosaicostracum, at the surface of the periostracum distal to the periostracal groove and immediately adjacent to the ectostracum (Plate 38, Figure 31). This transport of protein implies that the mantle is in intimate contact with the shell and the periostracum or that there is some mechanism that drives the proteins across the extrapallial fluid. It is most likely a combination of both, depending on when the secretion occurs. There is a detectable difference in electric potential across the mantle so the mechanism could be electrophoretic (WILBUR, 1964). The passive or carbohydrate compounds which may have a role in the process of calcification are derived from mucus cells adjacent to the mantle epithelial cells. They are found to be abundant outside the pallial line and particularly in the outer mantle fold and secrete a mucus-like compound best described as a mucoprotein or neutral polysaccharide (BEEDHAM, 1958). This mucus may play an active role in the transport of calcium or calcium salts and is necessary for lubrication of the mantle-shell interface. Essentially an environment conducive to shell formation is created by the mantle in the zone between the outer lobe and the periostracum. What the source and transport mechanism of the calcium is and how it enters into a reaction with the organic phase is a subject of great speculation in current research. The shell material is forming and this aspect can be interpreted on the basis of the interaction of the specific amino acids making up the shell protein, accepting the presence of the carbohydrate, and examining the patterns of calcification. It has been demonstrated that some pro-

teins can give evidence as to their stage of evolution by the number and sequence of amino acids in the peptide chain (ACHER, 1966). It has been proposed that there are active and passive sites in the protein-carbohydrate complex and that these active sites coincide with or are more prone to formation of the mineral components that form the shell. Theoretically these active sites are a specific amino acid or amino acid combination such as aspartic acid or glutamic acid or both (P.E. Hare, personal communication). Their position on the protein molecule responsible for the calcifying process is determined by the genetic nature at the species level of the material forming the patterns observed on the outer surface of the shell or the mosaicostracum.

The difference in size between the structures seen on the mosaicostracum and the individual protein fibers which contribute to the formation of the patterns is on the order of many hundred times. The protein fibers organize into a three-dimensional network before calcification begins in a configuration governed by the chemistry

Table 1

Estimated Percent Distribution of Mosaicostracum Showing Distinctive Pattern

<i>Tellina (Tellina) radiata</i>	95%
<i>Tellina (Moerella) salmonea</i>	95%
<i>Tellina (Laciolina) laevigata</i>	50%
<i>Tellina (Laciolina) magna</i>	25%
<i>Tellina (Phyllodina) squamifera</i>	25%
<i>Tellina (Phyllodina) persica</i>	25%
<i>Tellina (Merisca) cristallina</i>	95%
<i>Tellina (Merisca) aequistriata</i>	50%
<i>Tellina (Merisca) martinicensis</i>	25%
<i>Tellina (Eurytellina) angulosa</i>	75%
<i>Tellina (Eurytellina) alternata</i>	75%
<i>Tellina (Eurytellina) punicea</i>	95%
<i>Tellina (Arcopagia) fausta</i>	25%
<i>Tellina (Acorytus) gouldii</i>	75%
<i>Tellina (Scissula) similis</i>	95%
<i>Tellina (Scissula) iris</i>	95%
<i>Tellina (Angulus) versicolor</i>	95%
<i>Tellina (Angulus) carpenteri</i>	75%
<i>Tellina (Tellinella) listeri</i>	50%
<i>Tellina (Tellinella) virgata</i>	25%

of the protein-polysaccharide mix. Again, this network symmetry is determined by the genetic nature of the calcifying proteins and polysaccharides. There are probably networks which are common to many genera and families of bivalves but the specific characteristics are seen only in the subunit distribution which forms the

overall pattern. These subunits are generated at the previously mentioned specific sites on the protein molecule. The remanent of such a calcifying network is illustrated (Plate 38, Figure 34).

DISCUSSION

The previous sections have given evidence for the presence of a structure unique to each species of the Tellinidae studied by a technique with the electron microscope. These structures form patterns which are believed to be controlled by the genetic nature of the calcifying substrate of organic material. Furthermore, evidence has shown that the mosaicostracum is preserved in fossil material. One specimen of *Tellina (Arcopagia) gabbi* GARDNER, 1916, from the Upper Cretaceous, Monmouth formation, Brightseat, Prince Georges County, Maryland, and one specimen of *Tellina* sp. from the Upper Cretaceous, Ripley formation, Quitman County, Georgia were examined. Both specimens showed a well preserved mosaicostracum. This is the result of a durable layer of the periostracum covering the mosaicostracum. The necessary elements for a phylogenetic study of the mosaicostracum have been proposed concurrent with the theory that the portion of the periostracum covering the mosaicostracum will prevent diagenesis to a degree that overall morphology of the patterns will not be altered in the geological record. Tests on fossil bivalves through time and space where differences in environment of local diagenesis could be detected as well as variation in time of the structure of the patterns is the next step in confirming the time sequenced substitution of different amino acids acting to produce new and hopefully related patterns on the mosaicostracum. Such studies may not only elucidate the phylogeny of calcified tissues but also the type of calcification that can be considered as being primitive and advanced.

If these studies are made in conjunction with amino acid analyses of the shell proteins, new evidence may be gained to show more precisely the interrelationships of species, genera, families, etc., of bivalves. In the event these studies show that the mosaicostracum is subject to some degree of alteration in the geologic record, the usefulness of the techniques may be lost for the paleontologist but it will still give the neontologist a new tool to study the bivalves. At the outset an extensive study of modern bivalves may be more in order before going to the fossil record so that possible revisions of related species and genera may be confirmed or revised. Moreover, the phylogeny of modern bivalves may be better understood when the interrelationship of calcified patterns and genetically controlled organic calcifying substrates is fully understood.

A more qualified inference of the space relationships of the same species of Tellinidae is facilitated by recognizing geographic sites for the collection of specimens that best exhibit the designated pattern for the species. The patterns illustrated were selected from specimens which display the essential characteristics of the species based on the categorical system proposed in the previous section. The USNM collection numbers for the illustrated species are to be regarded as designating the locality where specimens of the species can be found which best show the pattern. This is intended to designate a type locality and population and not to designate a type specimen.

PHYLOGENETIC IMPLICATIONS OF THE PATTERNS

At the outset it was hoped that the patterns seen on each different species would be so distinct that possible taxonomic confusion resulting from a similarity between the

Explanation of Plate 32

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 13: *Tellina (Arcopagia) fausta* PULTENEY, 1799
USNM No. 461708

Figure 14: *Tellina (Acorylus) gouldii* HANLEY, 1846
USNM No. 383373

Explanation of Plate 33

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 15: *Tellina (Scissula) similis* SOWERBY, 1806
No Number

Figure 16: *Tellina (Scissula) iris* SAY, 1822 USNM No. 193052

Explanation of Plate 34

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 17: *Tellina (Angulus) versicolor* (COZZENS MS) DEKAY
USNM No. 462098

Figure 18: *Tellina (Angulus) carpenteri* DALL, 1900
USNM No. 219470

Explanation of Plate 35

Plan Views from Pt/C Single Stage Replicas of the Surface of the Mosaicostracum. $\times 15,000$

Figure 19: *Tellina (Tellinella) listeri* RÖDING, 1798
USNM No. 530399

Figure 20: *Tellina (Tellinella) virgata* LINNAEUS, 1758
USNM No. 17632



Figure 13

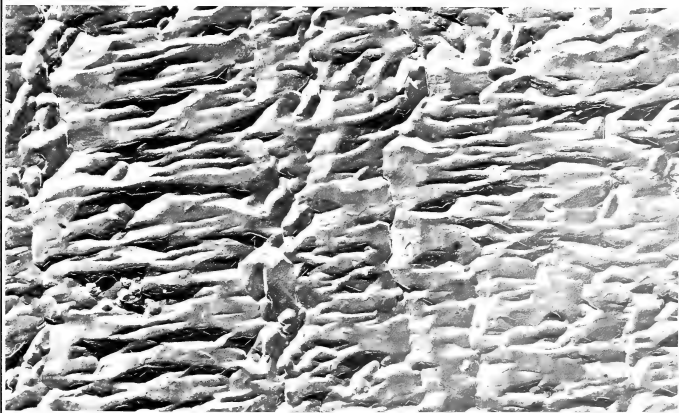


Figure 14



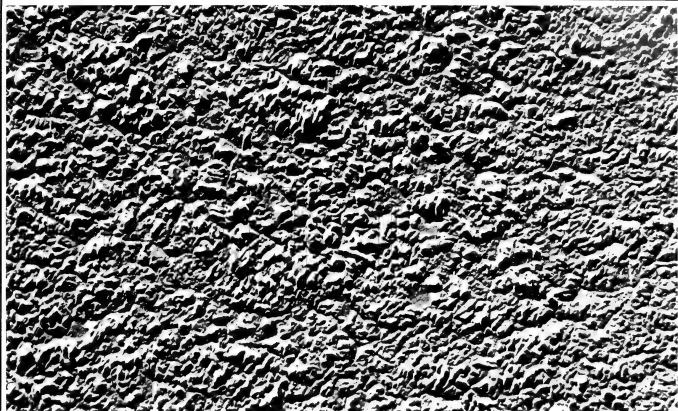


Figure 15

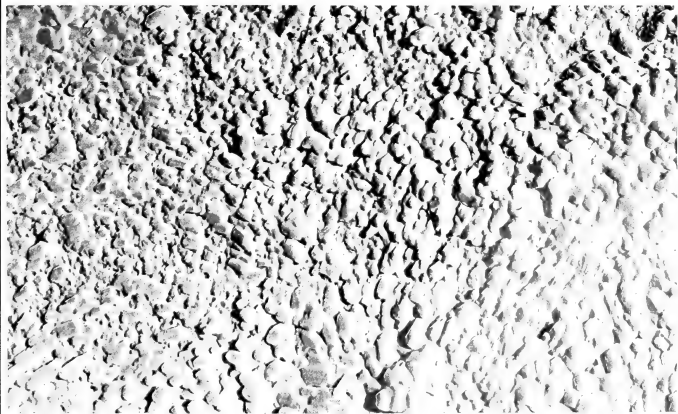


Figure 16



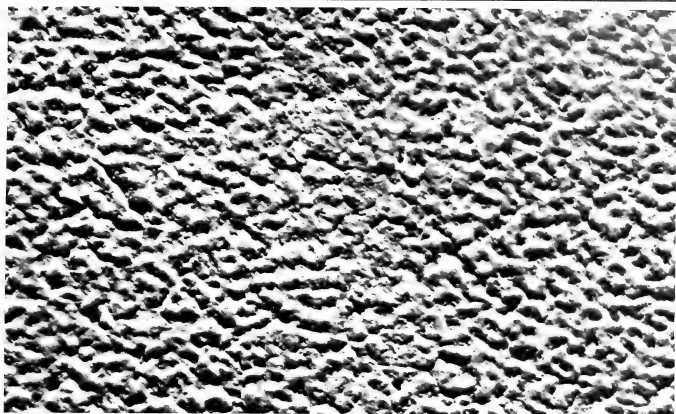


Figure 17

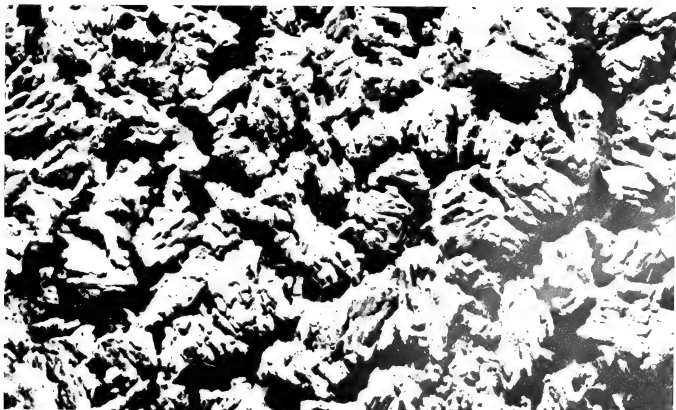


Figure 18



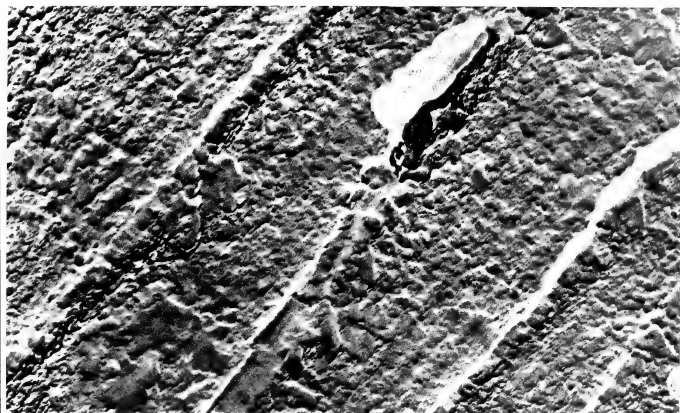


Figure 19

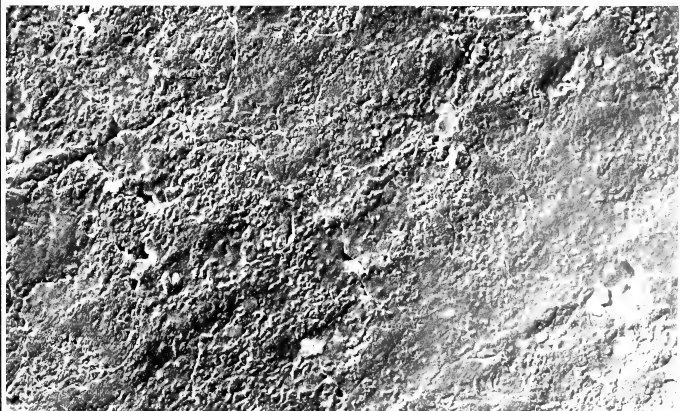


Figure 20



patterns would be avoided. The study demonstrated, however, that closely related, but not precisely similar patterns characterized many species. In some cases, species with very similar patterns represented the subgenera defined on macromorphological grounds. In a few cases species of different subgenera had similar patterns. These features and the apparent developmental sequence of patterns imply that the patterns are related phylogenetically.

The pattern groups were erected without a conscious pre-existing scheme in mind and only after attempts to establish the phylogenetic relationships of the patterns did it seem plausible to propose how the patterns are related and what the implications of such an arrangement might be. Some of the pattern similarities agree with Boss's (1966) divisions at the subgeneric level and some are distinct to such a degree that it would be a simple matter to regroup the species into different existing subgenera or to identify closely related subgenera. The criterion of any phylogeny is the progression from similar characteristic to similar characteristic until the two distinct end members are separated by a progression of interrelated features. The degree of complexity exhibited by the mosaic-tracum patterns serves as another basis for evaluating phylogenetic relationships within the Tellinidae. The basis of this phylogenetic scheme will be the degree of complexity that the patterns display. The degree of pattern complexity is divided into 3 major divisions: the simple group, the compound group, and the complex group. The schematic representation is shown in Table 2.

The simple pattern groups which are comprised of the mosaic, pustulose, crystalline, linear, and planar patterns will represent the basic pattern groups upon which to erect a hierarchy. These 5 groups are divided into 3 sets. (A), which is the mosaic set, contains the species *Tellina alternata*, *T. angulosa*, *T. punicea*, *T. carpenteri*, and *T. magna*. (B), which is the crystalline and pustulose set, contains the species *T. cristallina*, *T. martinicensis*, *T. iris*, *T. persica*, *T. acquistriata*, and *T. similis*. (C), which is the planar and linear set, contains the species *T. listeri* and *T. virgata*. (A) subset, which is the compound group pustulose-mosaic, contains the species *T. radiata* and *T. versicolor*. (B) subset, which is the compound group crystalline-pustulose, contains the species *T. salmonea*. (C) subset, which is the compound group crystalline-linear, contains the species *T. squamifera* and *T. gouldii*. (D), the last subset, is the complex group crystalline-linear - crystalline-pustulose - pustulose-linear, contains one species, *T. laevigata*.

Table 2

	SIMPLE	COMPOUND	COMPLEX
A Set	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Laciolina</i> <i>Eurytellina</i> <i>Eurytellina</i> <i>Eurytellina</i> <i>Angulus</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Mosaic</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> A Subset <i>Angulus</i> <i>Tellina</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Pustulose-Mosaic</div>	
B Set	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Merisca</i> <i>Scissula</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Pustulose</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> B Subset <i>Moerella</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Crystalline-Pustulose</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> D Subset <i>Laciolina</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Pustulose-Linear</div>
C Set	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Scissula</i> <i>Merisca</i> <i>Merisca</i> <i>Phyllodina</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Crystalline</div>	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> C Subset <i>Phyllodina</i> <i>Acorylus</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Crystalline-Linear</div>	
	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Tellinella</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Linear</div>		
	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Tellinella</i> <i>Arcopegia</i> </div> <div style="writing-mode: vertical-rl; transform: rotate(180deg); font-size: small;">Planar</div>		

Starting with set (A) it may be concluded that *Tellina* (*Laciolina*) *magna*, *T. (Eurytellina)* *angulosa*, *T. (E.) alternata*, *T. (E.) punicea*, and *T. (Angulus)* *carpenteri* are closely related. *Tellina (Angulus)* *versicolor* represents the transition species at the subgeneric level from the simple mosaic group to the compound pustulose-mosaic group and is also closely related to *T. (Tellina)* *radiata*. In set (B), *T. (Merisca)* *acquistriata* and *T. (Scissula)* *similis* are closely related as are *T. (S.) iris*, *T. (Merisca)* *martinicensis*, *T. (M.) cristallina* and *T. (Phyllodina)* *persica*. These species have no transition species at the subgeneric level to subset (B), which is represented by *T. (Moerella)* *salmonea*. Note that *T. salmonea* is a Pacific species. This could imply that some other unstudied species in the subgenus *Moerella* may have a transition pattern or that no transition pattern exists at the subgeneric level. *Tellina (Phyllodina)* *persica* is the transition species

to subset (C) and is related to *T. (P.) squamifera*, which is closely related to *T. (Acorylus) gouldii*. In set (C) *T. (Tellinella) listeri* is not as closely related to *T. (T.) virgata* and *T. (Arcopagia) gouldii* as it is to the species in subset (C). In set (C) there is no transition pattern at the subgeneric level and only an allusion of the relationship to subset (C) is seen with the linear pattern on *T. (Tellinella) listeri*. The species *T. fausta* and *T. virgata* seem to be more isolated than any of the other species in the simple pattern group. This could imply that the planar pattern is the most primitive in terms of its position in the phylogenetic hierarchy.

The compound group contains 5 species, each of which may be related at the subgeneric level to 2 common ancestors: *Tellina (Phyllodina) squamifera* and *T. (Angulus) versicolor*.

Subset (D), which contains one species, *Tellina (Laciolina) laevigata*, is the end member of the hierarchy. It probably represents the most advanced species of the 20 studied. Boss (1966) remarks that *Laciolina* representa-

tives have not been discovered in the fossil record of the Western Atlantic. It is noteworthy that most of the other subgenera studied do have fossil representatives.

The overall validity of the phylogeny can be justified by the number of species that share the same pattern. At the subgeneric level there are 3 species in *Eurytellina* confined to set (A), 3 species in *Merisca* and 2 in *Scissula* confined to set (B), and 2 species in *Tellinella* confined to set (C). The departure from this degree of similarity is better born out by the interrelationships of the patterns in the subsets.

The fact that simple patterns are combined with each other to form the compound patterns, and that the compound patterns are combined to form the complex patterns leads to the question as to how this sequence of combinations can be used to determine the phylogenetic relationship of the species and subgenera. Three assumptions can be made: (1) that the simple patterns are primary and the complex advanced phylogenetically and therefore the complex pattern represents a recombina-

Explanation of Plate 36

Figure 21: Oblique view, single stage Pt/C stage replica from contact of mosaicostracum with ectostracum fractured edge. Note mosaicostracum overhanging at middle and far right. *Tellina (Eurytellina) angulosa*. $\times 15\,000$

Figure 22: Oblique view, single stage Pt/C replica of concentric growth ridge showing continuity of mosaicostracum over ridge and two areas where the ridge is fractured revealing the underlying ectostracum and the mosaicostracum overhanging at the lower left and upper right. *Tellina (Eurytellina) alternata*. $\times 5\,000$

Figure 23: Oblique view, single stage Pt/C replica from contact of mosaicostracum with ectostracum at fractured edge. Note angular break of mosaicostracum lacking an overhang as in Figures 21, 22, and 24. *Tellina (Scissula) similis*. $\times 15\,000$

Figure 24: Oblique view, single stage Pt/C replica from contact of mosaicostracum with ectostracum fractured edge. Note mosaicostracum overhanging the contact. *Tellina (Eurytellina) alternata*. $\times 15\,000$

Explanation of Plate 37

Figures 25, 26, 27: Ontogenetic series with range in shell size by length 9 mm, 13 mm, 21 mm. Plan view, single stage Pt/C replica of mosaicostracum. *Tellina (Merisca) aequistriata*. USNM No. 40737. $\times 5\,000$

Figure 28: Plan view, single stage Pt/C replica of mosaicostracum from *Tellina (Merisca) aequistriata*. USNM No. 194658. $\times 5\,000$

Figure 29: Plan view, single stage Pt/C replica of mosaicostracum from *Tellina (Merisca) aequistriata*. USNM No. 461671. $\times 5\,000$

Figure 30: Plan view, single stage Pt/C replica of mosaicostracum from *Tellina (Merisca) aequistriata*. USNM No. 46309. $\times 5\,000$

Explanation of Plate 38

Figure 31: Diagrammatic sketch to illustrate a typical mantle-shell relationship and probable area (A) where the mosaicostracum is first formed. Not to scale. After BEEDHAM, 1958.

Figures 32 and 33: Plan view, single stage Pt/C replica of concentric growth ridge (GR) with mosaicostracum to either side of ridge and absent, probably due to abrasion, on top of ridge. Note organic material clinging to replica in Figure 33 along lower left edge of ridge. $\times 5\,000$

Figure 34: Plan view, single stage Pt/C replica of reticulated fibrous matrix which may be a bleach-insoluble calcifying network between the major portion of the periostracum and the mosaicostracum. Observed on all species with same general appearance. *Tellina (Tellina) radiata*. $\times 15\,000$

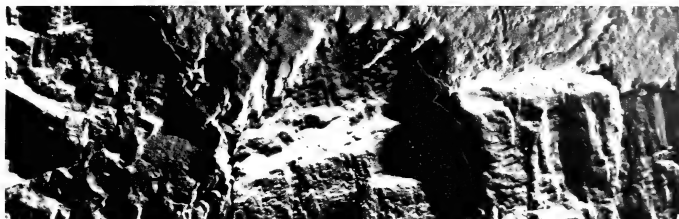


Figure 21

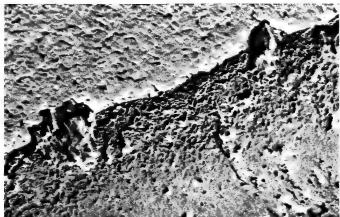


Figure 22

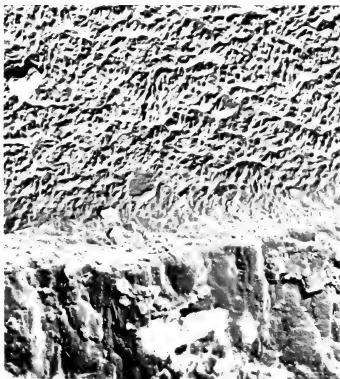


Figure 23



Figure 24



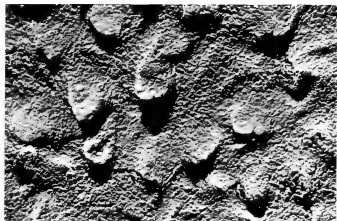


Figure 25



Figure 28

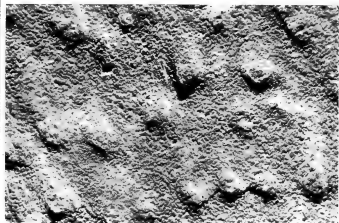


Figure 26

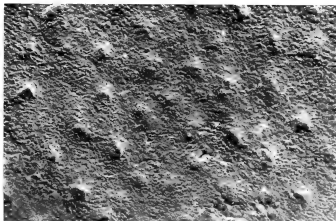


Figure 29

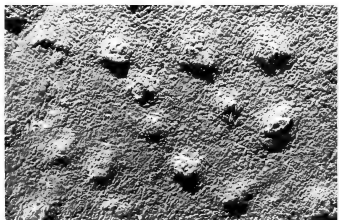


Figure 27

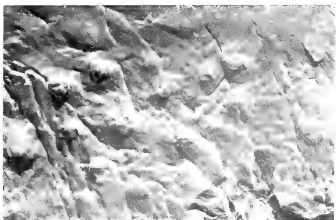


Figure 30



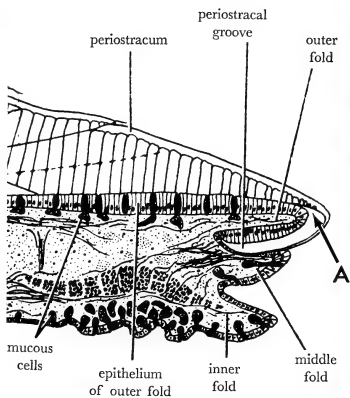


Figure 31

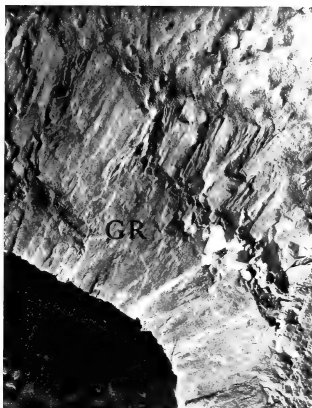


Figure 32



Figure 33

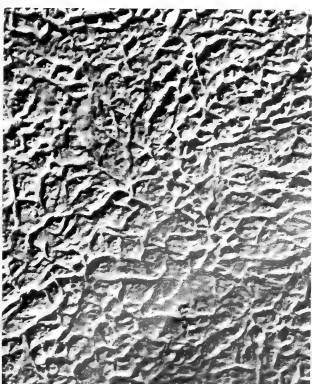


Figure 34



Table 3

Subgenus and Species	USNM Number	Locality	Number in Growth Series		Specimens Examined	
			Left	Right	Left	Right
			Valve	Valve	Valve	Valve
<i>Tellina</i>						
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	598232	Varadero Beach, Cuba	3	2	4	15
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	621563	Bermuda			1	
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	589833	Bimini, Bahamas	6			
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	360265	San Salvador			2	1
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	27175	Cedar Keys, Florida			1	3
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	440497	Haiti			2	1
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	161443	Miami, Florida			2	1
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	122222	La Guayra, Venezuela			2	1
(<i>Tellina</i>) <i>radiata</i> LINNAEUS, 1758	168854	Sanibel Island, Florida			2	1
(<i>Moerella</i>) <i>salmonica</i> (CARPENTER, 1864)	108634	Kiska Island, Alaska				2
(<i>Moerella</i>) <i>salmonica</i> (CARPENTER, 1864)	108649	Saint Paul, Alaska			3	
(<i>Moerella</i>) <i>salmonica</i> (CARPENTER, 1864)	13688	Monterey, California			1	2
(<i>Laciolina</i>) <i>laevigata</i> LINNAEUS, 1758	83354	Bermuda			1	2
(<i>Laciolina</i>) <i>magna</i> SPENGLER, 1798	36174	Tampa Bay, Florida				1
(<i>Laciolina</i>) <i>magna</i> SPENGLER, 1798	57151	East Coast, Florida				1
(<i>Laciolina</i>) <i>magna</i> SPENGLER, 1798	426098	Cuba				1
(<i>Laciolina</i>) <i>magna</i> SPENGLER, 1798	621627	Bermuda				1
(<i>Phyllodina</i>) <i>squamifera</i> DESHAYES, 1855	461776	Miami, Florida			2	1
(<i>Phyllodina</i>) <i>persica</i> DALL & SIMPSON, 1901	161780	Puerto Rico			2	1
(<i>Merisca</i>) <i>crustallina</i> SPENGLER, 1798	530395	Saint Thomas, Virgin Islands			1	2
(<i>Merisca</i>) <i>aequistriata</i> SAY, 1824	461671	Santa Lucia, Cuba			3	
(<i>Merisca</i>) <i>aequistriata</i> SAY, 1824	465309	Cape Hatteras, N. C.			1	
(<i>Merisca</i>) <i>aequistriata</i> SAY, 1824	194658	West Coast of Florida	4	1		
(<i>Merisca</i>) <i>martinicensis</i> D'ORRIGNY, 1842	42897	Saint Dominique			2	1
(<i>Eurytellina</i>) <i>angulosa</i> GMEIN, 1791	33740	Saint Croix			1	2
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	40536	Cape Hatteras, N. C.	3	4		
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	35836	Cape Hatteras, N. C.	3	3		
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	36173	Charleston Bay, S. C.	2	4		
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	461622	Texas			1	1
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	36608	Beaufort, N. C.			1	1
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	464192	West Florida			1	1
(<i>Eurytellina</i>) <i>alternata</i> SAY, 1822	46866	Florida			2	1
(<i>Eurytellina</i>) <i>punica</i> BORN, 1778	122226	La Guayra, Venezuela			3	
(<i>Arcopagia</i>) <i>fausta</i> PULTENEY, 1799	461708	Cabanas Bay, Cuba			1	2
(<i>Arcopagia</i>) <i>fausta</i> PULTENEY, 1799	56583	Vera Cruz, Mexico			2	1
(<i>Arcopagia</i>) <i>fausta</i> PULTENEY, 1799	53639	Key West, Florida			2	3
(<i>Arcopagia</i>) <i>fausta</i> PULTENEY, 1799	461709	Kings, Jamaica			1	2
(<i>Acorylus</i>) <i>gouldii</i> HANLEY, 1846	500913	Barbados			3	1
(<i>Acorylus</i>) <i>gouldii</i> HANLEY, 1846	383373	Jeremie, Haiti			1	
(<i>Scissula</i>) <i>similis</i> SOWERBY, 1806	no No.	Florida				3
(<i>Scissula</i>) <i>iris</i> SAY, 1822	429015	Cape Hatteras Pt., N. C.			2	
(<i>Scissula</i>) <i>iris</i> SAY, 1822	193052	Cameron, Louisiana			1	
(<i>Scissula</i>) <i>iris</i> SAY, 1822	426111	Saint Augustine, Florida			2	1
(<i>Scissula</i>) <i>iris</i> SAY, 1822	128435	South Carolina	1	4		
(<i>Scissula</i>) <i>iris</i> SAY, 1822	461670	Bimini, Bahamas			1	1
(<i>Angulus</i>) <i>versicolor</i> (COZZENS MS) DEKAY	40566	Cape Hatteras, N. C.	5	3		
(<i>Angulus</i>) <i>versicolor</i> (COZZENS MS) DEKAY	462123	Key West, Florida			3	2
(<i>Angulus</i>) <i>versicolor</i> (COZZENS MS) DEKAY	462098	Santa Lucia, Cuba			3	2
(<i>Angulus</i>) <i>carpenteri</i> DALL, 1900	219470	Chirikoff Island, Alaska			2	1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	461634	Miami, Florida				1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	27238	Tortugas, Florida			1	1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	426079	Havana, Cuba			2	1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	83334	Bermuda			2	1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	441522	Montego Bay, Jamaica				1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	393926	El Roque Island, Venezuela				1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	426323	Haiti			1	1
(<i>Tellinella</i>) <i>listeri</i> RÖDING, 1798	530399	Saint Thomas, Virgin Islands	6	4		
(<i>Tellinella</i>) <i>virgata</i> LINNAEUS, 1758	17632	Singapore, China			2	1

tion of genetic material from simple stocks; (2) that the compound groups represent links between simple pattern groups in which only one pattern mutated and introduced a new pattern; (3) that the complex and compound lineages are ancestral to simple lineages which represent genetic isolation of the simple pattern groups contained in the complex group.

SUMMARY

A newly discovered calcareous shell layer, the **mosaicost-racum**, forms a veneer between the ectostracum and periostracum of bivalve shells and externally displays distinct surface patterns when examined with the electron microscope at magnifications of 2500 \times and greater. These patterns appear to be taxonomically consistent at the species level and can generally be arranged in morpho-groups, some of which are compatible with existing sub-generic categories.

The family Tellinidae was chosen to test the constancy of the patterns at the generic, subgeneric and species levels under 5 parameters relevant to each tested species: 1. variation in the adult population; 2. variation between the right and left valves; 3. ontogenetic variation; 4. geographic variation; 5. variation over the area of a single valve with tests to compare the patterns between pigmented zones and unpigmented zones. Representative species for each subgenus of the Tellinidae (Boss, 1966) of the Western Atlantic and a few from the Pacific were tested. Two fossil Tellins were examined from the Late Cretaceous of Georgia and Maryland.

The species examined consistently displayed the same patterns regardless of the tested parameters and could be identified, on shell fragments alone, by this method. Patterns of species within a single subgenus are sometimes closely related, and the general patterns of genera and subgenera are distinct to varying degrees, suggesting that the ultrastructure of the mosaicost-racum is a potential tool for specific identification, and for the study of phylogeny and evolution in living and fossil bivalves. The probable origin of this layer is discussed.

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A New Species of *Strombina* from the Galápagos Islands

BY

WILLIAM K. EMERSON

AND

ANTHONY D'ATTILIO

Department of Living Invertebrates,
American Museum of Natural History

Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 39)

AMONG SEVERAL NEW or otherwise interesting mollusks received from Mrs. Jacqueline DeRoy of Academy Bay, Santa Cruz Island, The Galápagos Islands, are two specimens of an apparently new species of *Strombina*. We take pleasure in describing this species in honor of Mrs. DeRoy.

Strombina (Cotonopsis) deroyae EMERSON & D'ATTILIO,
spec. nov.

Diagnosis: This species may be distinguished from *Strombina (Cotonopsis) esmeraldensis* OLSSON, 1964, a precursor in the Ecuadorian Neogene, by having a much larger shell (attaining nearly twice the length of the fossil), with a less robust outline, a proportionately larger and more strongly recurved siphonal canal, and with finer spiral threads on the base of the body whorl.

Description: The shell is thin though large for the genus, surface smooth, except for first 4 post-nepionic whorls; spire extended; body whorl swollen, ending in a long recurved canal. The holotype is a well-preserved, but dead-collected specimen, lacking soft parts. The shell has 10 whorls, the nepionic whorls having been lost. The individual whorls of the spire are slightly convex; the suture is well-defined but simple; each of the 4 whorls of the spire are sculptured with about 11 axial ribs which extend the length of each whorl to give the suture a slight undulation; the ribs are about equal in size to the interspaces and gradually become obsolete on the fifth whorl. A few widely spaced spiral striae are present on the body whorl above the aperture; the lower half of

the body whorl is sculptured with numerous, closely set, rounded, spiral striae that continue in the same manner to the base of the siphonal canal. The length of the aperture and canal is about one half the height of the shell; the aperture is narrowly elliptical; the inner lip sinuously turns into the canal; the parietal region is poorly defined except below, along the siphonal canal; anteriorly a strong cord arises from within, on the inner lip, and curves around to join the labial edge to form an anal canal; in addition, the labrum is thickened anteriorly within by a large rounded knob-like plica furthering the formation of the anal canal; above this knob there are 2 smaller plicae. The lip edge is thickened into an axial cord above and diminishes below into a thin edge along the siphonal canal; within the labrum there are present below the knob forming the anal canal 12 to 14 lirations extending within the aperture for a short distance; the lirations are weakest anteriorly. The strongly recurved siphonal canal is widely open.

The opercular and radular characters are not known, as the holotype and paratype were both empty shells when dredged.

The color on the dorsum of the shell consists of a medium shade of brown broken up into a pattern arranged in axial, lightning-like streaks and daubs of brown over white in a broad band on the spire; the lighter area is directly below the suture; on the body whorl an additional lighter band is found starting anteriorly near the anal canal and divides the pattern on the body whorl more or less into 2 more lightly and 2 more heavily maculated areas.

Measurements: Holotype, 49 mm in length (early whorls missing), 26.7 mm in width (Plate 39, Figures 1

to 3). Paratype, 46 mm in length (early whorls missing), 25.4 mm in width (Plate 39, Figures 4 to 7).

Type Locality: Southeast of Academy Bay, Santa Cruz Island, dredged in 102 fathoms, April 26, 1967, by the DeRois.

Type Repositories: Holotype, American Museum of Natural History no. 146277; paratype, collection of Mrs. DeRoy.

Remarks: Except for the recently re-discovered Caribbean species, *Strombina pumilio* (REEVE, 1859) (WEISBORD, 1962; WOODRING, 1964), representatives of this New World genus are now confined to the warm waters of the eastern Pacific Ocean. We here add an additional species to the approximately 24 known from the Panamic faunal province (see KEEN, 1958, for a list of the living species). The genus flourished in the tropical western Atlantic and eastern Pacific during early to late Miocene time, ranging from the southeastern United States, the West Indies, to Venezuela, and from Costa Rica to Ecuador. In the Pliocene, its distribution became more limited, with species known only from Florida, Trinidad, Venezuela, Ecuador, and western Panama. With the closure of the trans-American seaways in the late Tertiary, only the above mentioned species is known to have survived in the western Atlantic. WEISBORD (1962, pp. 323-329) lists about 50 nominal species of *Strombina* reported as fossils from deposits ranging in age from early Miocene to late Pliocene. Of this number, only 4 of the records refer to living species.

The new species appears to represent a living representative of a small group of the genus that lacks a strombinoid hump on the body whorl. This group was afforded subgeneric recognition by OLSSON (1942, p. 227), who proposed the name *Cotonopsis*, with *Strombina* (*C.*) *panacostaricensis* OLSSON (1942, pp. 227, 228; pl. 23, fig. 5) the type of the subgenus. The type species is a fossil from the Pliocene Charco Azul formation of the Panamanian Burica Peninsula. According to OLSSON (1942, p. 227), a second, unnamed species of this group also occurs in these deposits. A third species, *S. (C.) esmeraldensis* OLSSON (1964, p. 148; pl. 28, figs. 3, 3a), which more closely resembles the present species, occurs in the Mio-Pliocene Esmeraldas formation at Quebrada Camarones, Ecuador. The Ecuadorian fossil is much

smaller than the new species, being only 25.9 mm in length, and it possesses a stouter appearance.

Of the known living species of *Strombina* (*sensu lato*) that lack a strombinoid hump, the shell of the new Galapagan species is reminiscent of *Strombina* (?*Cotonopsis*) *edentula* DALL, 1908, but the resemblance may be solely superficial. DALL's holotype, which has not been illustrated, has a shorter (34 mm in length) and stouter shell with a proportionately shorter and less recurved siphonal canal (*teste* A. A. Olsson, *in litteris*). DALL's type has each of the first 4 post-nepionic whorls ornamented with 14 to 15 axial ribs, whereas the new species has about 11 ribs on each of these whorls. *Strombina turrita* (SOWERBY, 1832), which is a living ally of *S. edentula*, also lacks denticulations or lirations of any sort on the inside of the outer lip. SOWERBY's taxon has a much smaller, more slender shell than that of the new species; and unlike the new species and *S. edentula*, it lacks axial ribs on the early whorls.

ACKNOWLEDGMENTS

In addition to Mrs. DeRoy, we are indebted to Dr. George E. Radwin of the San Diego Museum of Natural History, Mr. Axel A. Olsson of Coral Gables, Florida, Dr. James H. McLean of the Los Angeles Museum of Natural History, Dr. Leo George Hertlein of the California Academy of Sciences, Dr. Joseph Rosewater of the U. S. National Museum, and Mr. William E. Old, Jr. of the American Museum of Natural History, for various courtesies. Mr. Olsson and Dr. Radwin kindly read a draft of the manuscript.

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Explanation of Plate 39

Strombina (*Cotonopsis*) *deroyae* EMERSON & D'ATTILIO, spec. nov.

Figures 1 to 3: Holotype, A. M. N. H. no. 146277;

Figures 1-2: $\times 1.5$; Figure 3: early whorls greatly enlarged to show axial ribs

Figures 4 to 7: Paratype, DeRoy Collection; $\times 1.5$

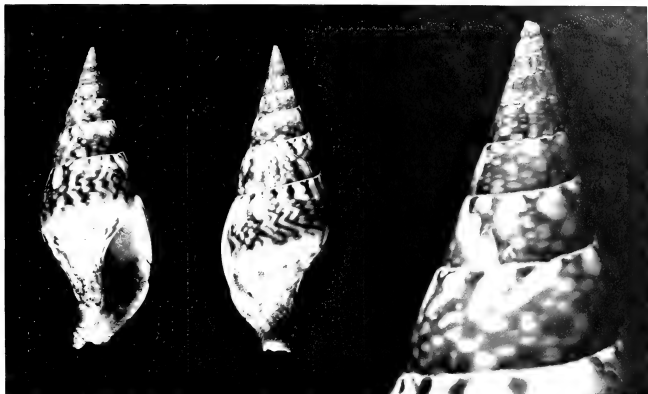


Figure 1

Figure 2

Figure 3



Figure 4

Figure 5

Figure 6

Figure 7



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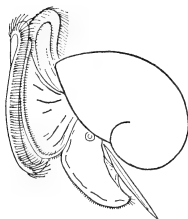
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A Note on Feeding and Excretion in Bivalves

BY

P. DINAMANI

Department of Marine Biology, University of Kerala

RECENT STUDIES on the faecal pellets of bivalve molluscs (KORNICKER, 1962; ARAKAWA, 1963, 1965) and on their rectum (JEGLA & GREENBERG, 1968) have drawn attention to yet another aspect of variation in the morphology and functioning of the gut of bivalves. There is, however, a facet of functional variation which I believe might be relevant to these studies and which came to my notice while I was conducting some feeding experiments on bivalves (*Mytilus*, *Cardium*), using different unialgal cultures. Some of the main points of these observations are:

- a) the form and type of faecal ribbon ejected from the animal was found to depend upon the time ingested material was retained within the gut;
- b) this was found to vary with the type of 'food' material used (or available to the animal), as well as the rate of its passage through the gut;
- c) with higher concentration of food material in the medium, strong rejectory mechanisms in the stomach caused ingested matter to be rejected and expelled rapidly as faeces, at times within 20 minutes of intake;
- d) faecal ribbons were initially composed wholly of unutilized 'food' (in my experiments, live algal cells) loosely bound with quantities of mucus;
- e) subsequent faecal ribbons were usually of a different texture, colour and form; and those expelled after an interval of 12 to 20 hours after intake were markedly different in these aspects from the first-formed ribbons; the quantity of mucus in the faeces usually proved to be an indicator of retention-time within the gut: [in *Mytilus* for example, faecal ribbons varied in cross-section from shapeless to oval to cylindrical mass, with a thick or thin or a separated keel-like part; and in colour from greenish to brownish shades;
- f) coarser material tended to be localized in faecal ribbons and these probably marked the sites of grooves in the gut.

Therefore, in classifying faecal ribbons on the basis of their physical characteristics, one has to take into account this variability which may be directly related to the amount and type of food available to the animal. KORNICKER (1962) has in fact recorded for filibranchs and eulamellibranchs a wide range of faecal types from 'un-

sculptured' to 'oval' to 'shapeless' masses. ALLEN (1961) and VAN WEEL (1961) have reported how faecal material may vary in colour varying with the time within the gut. Observations by LOOSANOFF & ENGLE (1947) and HAVEN & ALAMO (1966) may also be cited in this connection since these authors have drawn attention to negative correlation between faeces and total seston and to greater faecal production at lowest levels of seston in oysters. These reveal sources of variability in faecal production according to the amount and type of food available to continuous feeders such as the bivalves.

Another consideration is that though the term 'faeces' generally means all matter rejected from the gut, usually the larger sense that it specifies refuse matter **after digestion** is brought in by connotation. This is, for example, implied in the observations by JEGLA & GREENBERG (1968), who regard the "preparation and propulsion of fecal matter as an important and mandatory function of the rectum" in the bivalves also. The time of retention within the hindgut of ingested matter, as well as the rate of its passage through other regions of the gut are factors to be established for a more functional interpretation of these structures in the bivalves. There appears in fact to be a greater need for observations at different times in natural populations in the field in order to resolve many questions of bivalve nutrition.

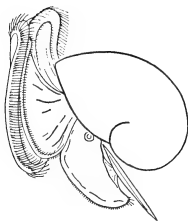
ACKNOWLEDGMENTS

I acknowledge with pleasure the kindness of the Director and Staff of the Marine Laboratory, Plymouth, where this work was carried out while I was in receipt of the Royal Society and Nuffield Foundation Commonwealth Bursary.

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Volutocorbis and *Fusivoluta*,
Two Genera of Deepwater Volutidae from South Africa

BY

HARALD A. REHDER

Senior Zoologist, Division of Mollusks

Smithsonian Institution, Washington, D. C. 20560

(Plates 40 to 43)

THE SUBMISSION SOME YEARS AGO by Mr. Clifton S. Weaver of Lanikai, Hawaii, and Mrs. Helen Boswell of Valhalla, Transvaal, South Africa, of specimens of deep-water species of volutes from South Africa for identification induced me to make a study of the species assigned to the genera *Volutocorbis* and *Fusivoluta*. To these individuals and to Mr. John E. duPont, Delaware Museum of Natural History, I give my thanks for the loan of important material. In addition, I am grateful to Dr. John A. Grindley, late of the South African Museum of Natural History, and to Mary Louise Penrith, Head of the Department of Marine Biology of that institution, for the loan of specimens studied by Barnard and for information regarding this material. Dr. R. Tucker Abbott of the Academy of Natural Sciences, Philadelphia, and Dr. Ruth D. Turner of the Museum of Comparative Zoology, Harvard University, have assisted this project by the loan of specimens.

In referring to specimens from these various institutions, I have used the following abbreviations:

ANSP	Academy of Natural Sciences, Philadelphia
DMNH	Delaware Museum of Natural History
MCZ	Museum of Comparative Zoology, Harvard University
SAM	South African Museum, Cape Town
USNM	United States National Museum

VOLUTIDAE FLEMING, 1822

Athletinae PILSBRY & OLSSON, 1954

Volutocorbis DALL, 1890*Volutocorbis* DALL, 1890, p. 75; BARNARD, 1959, p. 24

This name was originally proposed by Dall as a subgenus of *Volutilithes* SWAINSON, 1831, a taxon of which he

considered the type to be *Voluta spinosa* LAMARCK [= *Voluta spinosa* (LINNAEUS, 1767)] of the Paris Basin Eocene, but which is now recognized to have as type species *Voluta muricina* LAMARCK, 1803, also of the Paris Basin Eocene.

At that time, Dall recognized only four species as belonging to *Volutocorbis*: the type species *Voluta limopsis* CONRAD, 1860, Paleocene of Alabama and Texas, *V. lima* SOWERBY, 1823, from the Barton Beds of the English Upper Eocene, *V. digitalina* LAMARCK, 1811, of the Paris Basin Upper Eocene, and the Recent *V. abyssicola* ADAMS & REEVE, 1848.

COSSMANN (1899, p. 138), in reviewing the family Volutidae, considered *Volutocorbis* to be of only sectional value, placing it under *Volutilithes* s. str. To Dall's list of species he added two species from the Paleocene: *V. muricata* FORBES, 1846, from India and *V. radula* FORBES, 1846, from India and Brazil. The first is not a *Volutocorbis*, but the Indian specimens of *radula* appear to belong to a member of this group, while those from Brazil belong elsewhere in the Volutidae.

To the Eocene species he added *Volutocorbis crenulifera* BAYAN, 1870 (*V. crenulata* LAMARCK, 1803, not GMELIN, 1791) from the Lutetian (Middle Eocene) of the Paris Basin.

The Oligocene species that he cites as belonging here is not a *Volutocorbis* but possibly a species of *Athleta*.

The first worker to consider *Volutocorbis* a distinct genus was R. Bullen Newton in 1906, although other workers still considered it a subgenus or section of *Athleta*. Since 1931, however, the group has quite generally been given generic rank.

Table 1

The following list, undoubtedly incomplete, comprises the fossil species that appear to belong in *Volutocorbis*

	Age	Group, Stage, or Formation	Location
<i>Volutocorbis</i>			
<i>limopsis</i> (CONRAD, 1860)	Paleocene	Midway	Alabama, Texas
<i>texana</i> PLUMMER, 1933	Paleocene	Midway	Texas
<i>kerenensis</i> PLUMMER, 1933	Paleocene	Midway	Texas
<i>daviesi</i> (VREDENBURGH, 1923)	Paleocene	Ranikot	W. Pakistan
<i>burtoni</i> (VREDENBURGH, 1923)	U. Paleocene	U. Ranikot	W. Pakistan
<i>eugeniae</i> (VREDENBURGH, 1923)	U. Paleocene	U. Ranikot	W. Pakistan
<i>victoriae</i> (VREDENBURGH, 1923)	U. Paleocene	U. Ranikot	W. Pakistan
<i>indica</i> DOUVILLE, 1929	U. Paleocene	U. Ranikot	W. Pakistan
<i>rykesi</i> (d'ARCHIAC & HAIME, 1853)	U. Paleocene	U. Ranikot	W. Pakistan
<i>soriensis</i> EAMES, 1952	L. Eocene	M. Laki	W. Pakistan
<i>harnaensis</i> COX, 1931	L. Eocene	M. Laki	W. Pakistan
<i>graueri</i> (OPPENHEIM, 1915)	L. Eocene		Togo
<i>olsoni</i> PLUMMER, 1933	L. Eocene	L. or M. Wilcox	Texas
<i>stenzeli</i> PLUMMER, 1933	L. M. Eocene	L. Claiborne	Texas
<i>crenulifera</i> (BAYAN, 1870)	M. Eocene	Lutetian	France
<i>pyrenaica</i> (VILLALTA COMELLA, 1956)	M. Eocene		Spain
<i>pakistanica</i> EAMES, 1952	M. Eocene	Khirthar	W. Pakistan
<i>celebesensis</i> (DOLLFUS, 1915) ⁴	M. Eocene	? Lutetian	Celebes
<i>darchiaci</i> (DALTON, 1908)	U. Eocene		Burma
<i>digitalina</i> (LAMARCK, 1811)	U. Eocene	Bartonian	France, England
<i>ickei</i> (MARTIN, 1914)	U. Eocene	Nanggoelan	Java

⁴ This species was originally assigned to the Oligocene by DOLLFUS.

The single specimen undoubtedly came from nearby beds of Eocene age (see MARTIN, 1917)

Certain other species originally allocated to *Volutocorbis* belong to other genera. Thus, *meridionalis* OLSSON, 1944, from the Upper Cretaceous of Peru and *oregonensis* TURNER, 1928, from the Eocene of Washington are not members of *Volutocorbis*. *Volutocorbis exornata* PETHO, 1906, from the Upper Cretaceous of Hungary is close to *Lyria*. *Volutospina multispinosa* NEWTON, 1922, from the Upper Eocene of Nigeria was placed by EAMES (1957, p. 46) in *Volutocorbis*, but this species also does not belong here. Many of the species placed by PLUMMER (1933, pp. 381-384) in *Volutocorbis* belong to *Athleta*.

At the present time, four living species, all occurring in the waters off the South African Coast, have been assigned to this genus. These are discussed below along with the description of two new species.

BURNETT SMITH (1906) has shown effectively that *Volutocorbis limopsis* CONRAD of the Midway Paleocene is the ancestral form of a phylogenetic line that evolved into the Oligocene species that are now placed in *Athleta*

(*Volutispina*). A similar phylogenetic evolution can undoubtedly be traced out among some of the European species of this complex.

In the following systematic review of the Recent species of the genus, I have figured two of the fossil species to demonstrate their resemblance to some of the Recent species (Plate 42, Figures 26-30).

The genus *Volutocorbis* is represented only in the Paleocene, Eocene, and Recent, and the considerable gap in time between the fossil species and those found living today, amounting to some forty million years, led me to try to find some tangible differences between the two groups of species. Although some species such as *V. abyssicola* have evolved characteristics quite divergent from the fossil forms, other recent species resemble the fossil species closely in shape and sculpture; for instance, *V. gilchristi* SOWERBY looks very much like *V. digitalina* (LAMARCK). I am, therefore, constrained to retain both Recent and fossil species in the one genus.

The geographic distribution of this genus in the Pale-

ocene and Eocene coincides very closely with the extent of the Tethys Sea, with the living forms now restricted to the deeper waters off South and Southeast Africa.

The protoconch in almost all shells of Recent species that I have seen has been so eroded that the outer shell layer is gone, leaving what appears to be the inner calcitic shell layer. Our single specimen of *Volutocorbis gilchristi* SOWERBY does show part of the complete protoconch, and from an examination of the latter, we see that it is short and obtuse, consisting of $1\frac{3}{4}$ smooth glossy whorls (Plate 40, Figure 1). The thin, outer glossy layer in this specimen has become chipped away in places revealing the dull calcitic layer underneath.

The protoconch of *Volutocorbis limopsis* (CONRAD) has a more slender smooth nucleus of slightly over 2 whorls, but specimens of *V. digitalina* (LAMARCK) from the Bartonian Upper Eocene of England show a more broadly conical protoconch of about $2\frac{1}{2}$ whorls (Plate 40, Figure 2), resembling that found in the Recent *V. disparilis* REHDER, new species.

Volutocorbis abyssicola (ADAMS & REEVE, 1848)

(Plate 40, Figure 3; Plate 41, Figures 10 to 13)

Voluta abyssicola ADAMS & REEVE, 1848, p. 25, pl. 7, fig. 6
Volutilithes abyssicola (ADAMS & REEVE), WOODWARD, 1900,
 p. 121; SOWERBY, 1902, p. 97, pl. 2, fig. 6
Volutocorbis abyssicola (ADAMS & REEVE), BARNARD, 1959, p.
 25, figs. 7a, 9a

Distribution: In 85 - 300 fathoms off the South African coast from off Hondeklipbaai, Namaqualand, western South Africa, to the southern edge of Agulhas Bank.

Remarks: A distinctive species, reaching on occasions a relatively large size (97 mm), it is characterized by its elongate-ovate shape and strong reticulation of axial and spiral sculpture, particularly on the penultimate whorl; the body whorl occasionally shows a greater prominence of the spiral sculpture. The eroded apical whorls suggest a broadly conical protoconch of 2 whorls or less (Plate 40, Figure 3).

BARNARD (1959, pp. 26 - 27) included specimens of *Volutocorbis lutosus* KOCH and *V. boswellae* REHDER (described in this paper) in his concept of *V. abyssicola*. The characters differentiating the latter from *V. lutosus* and *V. boswellae* will be discussed under these species.

This species varies considerably in size and somewhat in shape, as well as in the strength and number of the columellar plaits. A comparison of Figures 11 and 12 shows a marked difference in breadth of shell and length of spine. I have seen two specimens (DMNH 19306 and Helen Boswell Collection) from 300 fathoms off Agulhas Bank that are somewhat heavier, with a shorter broader spine, a thickened, rather straight outer lip which is distinctly angulate near its juncture with the body whorl (Plate 41, Figure 13).

Volutocorbis lutosus KOCH, 1948

(Plate 40, Figure 6; Plate 41, Figures 14, 15)

Volutocorbis lutosus KOCH, 1948, pp. 5 - 6, pl. 2
Volutocorbis abyssicola var. *lutosus* KOCH, BARNARD, 1959, p. 27

Distribution: In 40 - 100 fathoms off the western coast of South Africa, from 14 miles almost due south of Cape of Good Hope to the mouth of the Orange River.

Remarks: I am retaining this as a species distinct from *Volutocorbis abyssicola* because of its very striking characters: broad-oval shape, shorter body whorl, more or less distinctly shouldered below the suture, and fewer and more irregular folds on the columella. This species seems to inhabit somewhat shallower water than *V. abyssicola* does, and specimens are frequently more or less encased in a hard, reddish-brown clay. It has to date been found only on the western side of South Africa and off the western slope of the Agulhas Bank.

The sculpture on the penultimate and antepenultimate whorls is more distinctly and distantly clathrate than on the body whorl, and the axial sculpture on the last whorl, when present in unworn specimens, consists of more or less distant ribs diminishing in strength towards the base.

The rather slender, elevated protoconch apparently consists of about $1\frac{1}{2}$ whorls (Plate 40, Figure 6).

Volutocorbis boswellae REHDER, spec. nov.

(Plate 40, Figure 5; Plate 41, Figures 16 to 19)

Diagnosis: Shell glossy, generally smaller than *Volutocorbis abyssicola* ADAMS & REEVE, with strong axial ribs, and with the spiral sculpture restricted to the subsutural

Explanation of Plate 40

- Figure 1: *Volutocorbis gilchristi* (SOWERBY), USNM 652796
 Figure 2: *Volutocorbis digitalina* (LAMARCK), USNM 645874
 Figure 3: *Volutocorbis abyssicola* (ADAMS & REEVE),
 USNM 631849
 Figure 4: *Volutocorbis disparilis* REHDER, SAM A3335

- Figure 5: *Volutocorbis boswellae* REHDER, SAM A2011
 Figure 6: *Volutocorbis lutosus* KOCH, SAM A2012
 Figure 7: *Fusivoluta blazeti* (BARNARD), SAM A3433
 Figure 8: *Fusivoluta clarkei* REHDER, DMNH 12833
 Figure 9: *Fusivoluta barnardi* REHDER, DMNH 10751

Magnification: $\times 3.75$

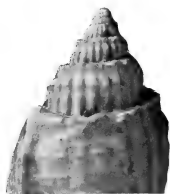


Figure 1

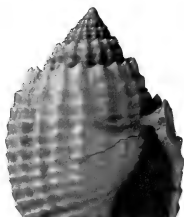


Figure 2

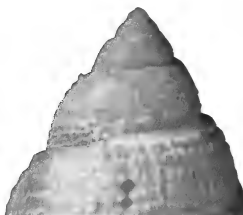


Figure 3



Figure 4



Figure 5

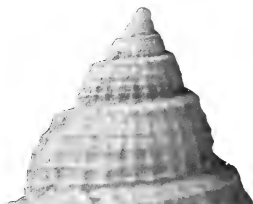


Figure 6



Figure 7



Figure 8



Figure 9



area and the lower half of the last whorl.

Distribution: In 80 - 300 fathoms off South Africa, from Saldanha Bay to Cape Seal.

Description: Shell elongate-ovate in shape, glossy, light yellowish-brown to dark orange-yellow in color¹; some specimens, particularly immature ones, show several rows of squarish maculations of moderate reddish-orange color. Nuclear whorls 2 - 2+, bulbous, subcylindric, with large initial whorl. Postnuclear whorls moderately convex, strongly ribbed, with a pronounced shoulder at the suture. Ribs bluntly and broadly angulate, gradually noticeably flattening out towards the base of the body whorl; ribs spinosely nodulate at sutural shoulder, sometimes causing whorl to appear channeled at suture; ribs below subsutural row of nodules are depressed followed by a pointed nodulation and another very shallow depression; the result is that whorls in their upper part appear to be encircled by 2 rows of rather sharp nodules separated by a shallow channel, the upper one being stronger. Upper half of whorl below nodulation without any spiral sculpture, lower half of body whorl marked by broad, shallow grooves very gradually increasing in strength anteriorly; in some specimens these grooves are faintly noticeable in upper portion of body whorl. Aperture narrow, broadly acuminate at posterior end, broad, with a shallow sinus at anterior end. Outer lip in adult specimens with an external, whitish, rather heavy callus, somewhat thickened and faintly denticulate within. Columella with 9 to 11 spiral folds increasing in strength anteriorly; immature specimens usually show from 4 to 9 thin folds. A thin whitish glaze, more or less sharply delimited, covers last whorl in columellar area.

Holotype: In 300 fathoms off Mosselbaai (Mossel Bay), South Africa (USNM 683585).

Measurements (in mm)

	height	diameter	locality
Holotype	59.1	25.0	off Mosselbaai
Paratype	34.35	16.5	off Cape Town
Paratype	36.35	17.7	off Cape Town
Paratype	29.5	15.3	off Cape Town
Paratype	34.5	15.4	off Cape Town
Paratype	36.3	17.0	off Cape Town
Paratype	28.9	15.3	off Cape Town

Eight other paratype specimens in the collection of the South African Museum from 4 stations off San Sebas-

tian Bay to Cape Seal in 85 - 90 fathoms vary in length from 24.6 to 43.5 mm.

One paratype in the Helen Boswell collection from off Saint Sebastian Bay in 80 - 100 fathoms measures 28.3 mm in height and 11.2 mm in diameter (Plate 41, Figures 15, 16). Another paratype (DMNH 19308) from the same locality measures 24.7 mm in height, and 10.9 mm in diameter.

Remarks: I have been able to examine some of the material that K. H. Barnard used in his discussion of this group of species (BARNARD, 1959, pp. 26 - 27). The specimens with reduced spiral sculpture to which he refers belong to this species and not to *Volutocorbis abyssicola*. It should be pointed out that *V. abyssicola* and *V. boswellae*, as well as the following species, *V. disparilis*, have all been collected together at one station, A3335 in 80 to 100 fathoms.

The differences between *Volutocorbis abyssicola* and *V. boswellae* are well marked, and in the material I have examined I have found no intermediate forms. Not only is the spiral sculpture greatly reduced in *V. boswellae*, but the axial ribs are much fewer in number, numbering 36 in one specimen of *V. boswellae* while in a comparable specimen of *V. abyssicola* the ribs number 60. The subsutural nodes are stronger in *V. boswellae*, which makes the furrow below much more pronounced. The surface in all fresh specimens I have seen of *V. abyssicola* is dull, whereas *V. boswellae* has a glossy surface.

Volutocorbis disparilis REHDER, spec. nov.

(Plate 40, Figure 4; Plate 41, Figures 20 to 22)

Diagnosis: Close to *Volutocorbis boswellae* but smaller, more inflated, with whorls of the spire proportionately broader, the subsutural series of projections not as pointed but more rounded, and the protoconch broadly conical with about 2½ whorls and a small pointed apex.

Distribution: Between Cape Town and Mosselbaai, South Africa in 80 - 300 fathoms.

Description: Shell glossy when fresh, dark grayish-yellow in color, rather broadly ovate. Protoconch consisting of 2½ to 2¼ whorls, broadly trochoid, with pointed apex and small initial whorl. Postnuclear whorls moderately convex, regularly ribbed, sharply shouldered at the shoulder where the ribs are marked by an angulate laterally compressed node; below the first series of nodes is a broad spiral groove, followed by another series of obtuse nodes on the ribs, and below that by another broad depression; as in *Volutocorbis boswellae* the latter 2 spiral grooves are caused by the nodes on the ribs and are not marked

¹ Color terminology in this paper from the ISCC-NBS Method (KELLY & JUDD, 1965)

on the body of the whorl. Central part of body whorl similarly sculptured by ribs and spiral rows of nodules, but showing more or less distinct but narrower spiral grooves; lower half with distinct but broader spiral grooves, rendering ribs closely nodulose. Aperture narrow with shallow sinus at anterior end. Outer lip in adults with a rather thin external callus, and somewhat thickened and faintly denticulate within; parietal wall with callus on lower half, bearing 7 to 8 spiral folds, the anterior one largest; immature specimens show only 3 slender folds on anterior part of parietal wall.

Holotype: In 80 - 100 fathoms, 36°40' S, 21°26' E (125 miles off Saint Sebastian Bay), Station A3335, southern slope of Agulhas Bank, South Africa (SAM A3335).

Paratypes: One specimen in South African Museum from Station A3335; two specimens (USNM 683651) from 300 fathoms, off Agulhas Bank; three specimens (DMNH 10760) also from 300 fathoms, Agulhas Bank.

Measurements (in mm)

		height	diameter
Holotype	SAM A3335	29.2	14.0
Paratype	SAM 3335	30.7	14.6
Paratype	USNM 683651	36.4	16.0
Paratype	USNM 683651	32.85	15.1
Paratype	DMNH 10760	31.5	17.4
Paratype	DMNH 10760	30.9	13.5
Paratype	DMNH 10760	30.2	14.0

Remarks: The combination of characters that separate this species from both *Volutocorbis abyssicola* and *V. boswellae* are such that I am constrained to consider it distinct, and because all three have been brought up in one dredge haul and are clearly distinguishable without any cross-over of characters I cannot but consider them to be three species.

Explanation of Plate 41

Figure 10: *Volutocorbis abyssicola* (ADAMS & REEVE), Coll. Helen Boswell (x 1)

Figure 11: *Volutocorbis abyssicola* (ADAMS & REEVE), ANSP 204528 (x 1)

Figure 12: *Volutocorbis abyssicola* (ADAMS & REEVE), USNM 612629 (x 1)

Figure 13: *Volutocorbis abyssicola* (ADAMS & REEVE), DMNH (x 1)

Figure 14: *Volutocorbis lutosus* KOCH, USNM 592439 (x 1)

Figure 15: *Volutocorbis lutosus* KOCH, USNM 612628 (x 1)

Volutocorbis gilchristi (SOWERBY, 1902)

(Plate 40, Figure 1; Plate 42, Figures 23, 24)

Volutulites gilchristi SOWERBY, 1902, p. 99, pl. 2, fig. 5

Volutocorbis gilchristi (SOWERBY), BARNARD, 1959, p. 28

Distribution: In 160 - 200 fathoms off the coast of Natal, from Durban to northern Zululand.

Remarks: This distinctive species is characterized by its small size (25.2 to 30 mm long), strong axial sculpture, and deeply channelled suture. The specimen figured (USNM 652796), taken from a specimen of *Xenophora pallidula* REEVE, 1843 trawled in 160 - 180 fathoms off Zululand, fortunately had the nuclear whorls fairly well preserved.

The protoconch (Plate 40, Figure 1) is globosely low-spired, consisting of 1½ large smooth, glossy whorls; the thin outer shell layer is broken away in places, revealing the dull shell layer below that is seen in most specimens of *Volutocorbis*. The inner edge of the outer lip is weakly denticulate as BARNARD (1959, p. 28) mentions, bearing a series of low, rounded, somewhat distant nodules. The columellar folds in this specimen number seven.

Measurements: Height, 25.2 mm; width, 11.8 mm. USNM 652796.

Volutocorbis epigona (MARTENS, 1904)

(Plate 42, Figure 25)

Voluta epigona MARTENS, 1904, pp. 106 - 107, fig.

Volutocorbis epigona (MARTENS), BARNARD, 1959, p. 28

Distribution: In 224 fathoms off Dar es Salaam, Tanzania.

Remarks: The three specimens and one fragment on which Martens based his description are apparently the only known representatives of this species. For the sake of completeness, I have reproduced the drawing that

Figures 16 & 17: *Volutocorbis boswellae* REHDER, spec. nov., Holotype USNM 683585 (x 1)

Figures 18 & 19: *Volutocorbis boswellae* REHDER, spec. nov.

Paratype, Collection Helen Boswell (x 1.7)

Figure 20: *Volutocorbis disparilis* REHDER, spec. nov., Paratype DMNH

Figure 21: *Volutocorbis disparilis* REHDER, spec. nov., Paratype DMNH

Figure 22: *Volutocorbis disparilis* REHDER, spec. nov., Holotype SAM A3335 (x 1.75)



Figure 10



Figure 11

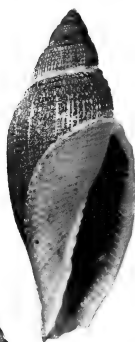


Figure 12



Figure 13



Figure 14



Figure 15



Figure 16



Figure 17



Figure 18



Figure 19



Figure 20

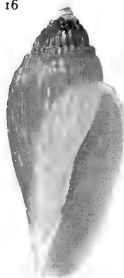


Figure 21



Figure 22



accompanies the original description. This species differs from all other living species in the strong subspinose sculpture and the internal liration of the outer lip.

The sculpture of *Volutocorbis epigona* bears considerable resemblance to the type species *V. limopsis* (CONRAD) from the Paleocene of Alabama and Texas, except that *V. limopsis* bears strong spiral furrows within the aperture behind the outer lip. *Volutocorbis epigona* has an even closer resemblance to *V. ickei* MARTIN, 1914, of the Upper Eocene of Java, in general shape and in the presence of internal furrows (or ridges) on the inside of the outer lip.

Volutocorbis limopsis (CONRAD, 1860)

(Plate 42, Figures 26, 30)

Volutilithes limopsis CONRAD, 1860, p. 292, pl. 7, fig. 24
Volutilithes (Volutocorbis) limopsis CONRAD, DALL, 1890, p. 75
Volutocorbis limopsis (CONRAD), NEWTON, 1906, p. 10

Distribution: Alabama and Texas, in the Midway group of the Paleocene.

Remarks: This species has two folds near the base of the columella with occasionally a smaller one in between.

The specimens figured (USNM 137044) were collected at Matthews Landing, Wilcox County, Alabama.

Volutocorbis digitalina (LAMARCK, 1811)

(Plate 40, Figure 2; Plate 42, Figures 27 to 29)

Buccinum scabriculum SOLANDER in BRANDER, 1766, p. 33, pl. 5, fig. 71 (not LINNAEUS, 1758)
Voluta digitalina LAMARCK, 1811, p. 77; DESHAYES, 1824, p. 693, pl. 93, figs. 1-2
Voluta lima SOWERBY, 1823, p. 136, pl. 398, fig. 2

Distribution: France and England, in the Bartonian Stage of the Upper Eocene.

Remarks: This species resembles in general shape *Volutocorbis gilchristi* SOWERBY but has strongly cancellate sculpture and possesses three or four folds on the lower part of the columella.

The specimens figured are from the Paris Basin (Plate 42, Figures 24, 25, USNM 644670) and from the Isle of Wight, England (Plate 42, Figure 26, USNM 644671).

Fusivoluta VON MARTENS, 1902

Fusivoluta VON MARTENS, 1902, p. 237; BARNARD, 1959, p. 29

I consider this genus to comprise 7 deepwater species which I discuss below. They occur from off South Africa

to off Kenya, East Africa. *Fusivoluta elegans* BARNARD (1959, p. 32), described from off East London, South Africa, does not appear to be a *Fusivoluta* and may belong in the Fusinidae.

The type of *Fusivoluta* is *Fusivoluta anomala* (VON MARTENS), designated by M. SMITH (1942, p. 17).

Fusivoluta pyrrhostoma WATSON, 1882

(Plate 42, Figure 31)

Fusus (Sipho) pyrrhostoma WATSON, 1882, p. 374; WATSON, 1886, p. 208, pl. 12, fig. 2
Neptunopsis pyrrhostoma (WATSON) SOWERBY, 1903, p. 226, pl. 3, fig. 1
Fusivoluta pyrrhostoma (WATSON), MARTENS, 1904, p. 32, pl. 3, fig. 15; BARNARD, 1959, p. 29, fig. 7 (b, c), 9 (b, c)

Distribution: In 39-200 fathoms off the coast of South Africa, from Cape Saint Blaize to Saldanha Bay.

Remarks: Large examples of this species were named *forma major* by BARNARD (1959, p. 30). From an examination of 12 specimens of this large form, ranging in length from 55.9 mm to 83 mm, I can see no reason for giving these specimens a distinctive name, even of infraspecific rank.

Fusivoluta capensis (THIELE, 1925)

(Plate 42, Figure 32)

Glypteuthria (?) capensis THIELE, 1925, p. 179, pl. 19, fig. 27
Glypteuthria capensis TOMLIN, 1932, p. 165, fig. 6 (not THIELE)
Glypteuthria sculpturata TOMLIN, 1945, p. 135
Fusivoluta capensis (THIELE), BARNARD, 1957, p. 210; BARNARD, 1959, pp. 30-31
Fusivoluta capensis (THIELE), WEAVER, 1965, p. 7, figs. 5, 6

Distribution: In 250-560 fathoms from off Cape Point to off Danger Point, South Africa.

Remarks: A distinct species because of its less fusiform shape and stronger spiral sculpture.

Measurements: Height 30.4 mm; diameter 13.0 mm (DMNH 10668) figured. Height 30.0 mm; diameter 12.5 mm (DMNH 10123).

Fusivoluta anomala (MARTENS, 1902)

(Plate 42, Figure 33)

Voluta (Fusivoluta) anomala MARTENS, 1902, p. 237
Fusivoluta anomala (MARTENS), 1904, pp. 107-108, pl. 3, fig. 14

Distribution: In 257-480 fathoms from north of Zanzibar Island to off Takaunga, Kenya.

Remarks: I have seen no specimens of this species, which is isolated geographically from the other species of the genus. The whorls are more convex and angulate, and the anterior canal seems to be more strongly twisted.

Fusivoluta decussata BARNARD, 1959

(Plate 42, Figure 34)

Fusivoluta decussata BARNARD, 1959, p. 31, fig. 8c

Distribution: In 310 fathoms, 15 miles off mouth of Buffalo River, East London, South Africa.

Remarks: This species was assigned to *Fusivoluta* with some doubt by Barnard, and because of its general form and nature of the nuclear whorls, it may provisionally remain in this genus. I have not seen specimens of this species.

Fusivoluta blazei (BARNARD, 1959)

(Plate 40, Figure 7; Plate 43, Figures 35, 36)

Fulguraria blazei BARNARD, 1959, p. 28, fig. 8 (b)

Fusivoluta blazei (BARNARD), WEAVER, 1963, p. 1; WEAVER, 1964, p. 2 (in part)

Distribution: In 105-125 fathoms on southern slope of Agulhas Bank off Cape Saint Blaize, South Africa.

Remarks: Barnard undoubtedly placed this species in *Fulguraria* largely because of the presence of a fold at the base of the columella. Undoubtedly, however, he intended to compare his new species with the Japanese species now placed in *Psephaea* CROSSE, 1871, and not with *Fulguraria*, which has a large, bulbous protoconch, and 8 to 12 folds on the columella. From *Psephaea*, however, this species also differs in the nature of protoconch, the weakness of the columellar fold, and in the proportionately shorter aperture and greater length of the spire.

Until more adult specimens are found, I follow Weaver in assigning this species to *Fusivoluta*. The presence of a weak columellar fold may be a juvenile character.

I have not seen a specimen, but through the kind cooperation of Mr. John E. duPont, I am reproducing photographs taken by him of the holotype in the South African Museum.

Fusivoluta clarkei REHDER, spec. nov.

(Plate 40, Figure 8; Plate 43, Figures 37 to 39)

Diagnosis: Shell rather large, solid, fusiform, of a yellowish flesh color; protoconch of 2 whorls, first $\frac{1}{2}$ whorl low, submersed, rest of protoconch with axially oriented nodules; early postnuclear whorls more or less angulate, with prominent axial ribs, which become obsolete on the fourth to sixth postnuclear whorl; postnuclear whorls with fine, sharp, subequal, spiral cords.

Distribution: In 240-300 fathoms off Lourenço Marques District, Mozambique.

Description: Shell dull when fresh, color grayish-yellowish pink, covered with a thin, adherent pale brownish-pink periostracum; elongate-fusiform in shape. Protoconch of about 2 nuclear whorls, usually rather worn, first nuclear whorl low, submersed, subsequent nuclear whorls made angulate by axial peripheral nodules (14 in last nuclear whorl of holotype); first postnuclear whorl shows commencement of spiral cords which gradually increase in strength and number, crossing the strong axial ribs, and becoming rather distant; spiral cords number 18 on antepenultimate whorl; on penultimate and ultimate whorl weak threads are often present in the interspaces; axial ribs become weak on fifth postnuclear whorl and disappear on the penultimate and ultimate whorls. Outer lip effuse, occasionally somewhat thickened, and with a broad shallow sinus just above the periphery; internally the outer lip is somewhat thickened, rarely very strongly so, color moderate yellowish-pink in contrast to the pale to light yellowish-pink color of the rest of aperture.

Explanation of Plate 42

Figures 23 & 24: *Volutocorbis gilchristi* (SOWERBY),

USNM 652796 (x 2)

Figure 25: *Volutocorbis epigona* (MARTENS), copy of original figure (x 1.4)

Figure 26: *Volutocorbis limopsis* (CONRAD), USNM 137044 (x 2)

Figures 27 & 28: *Volutocorbis digitalina* (LAMARCK),

USNM 644670 (x 2)

Figure 29: *Volutocorbis digitalina* (LAMARCK), USNM 644671

(x 2)

Figure 30: *Volutocorbis limopsis* (CONRAD), USNM 137044 (x 2)

Figure 31: *Fusivoluta pyrrhostoma* (WATSON), USNM 612611 (x 1)

Figure 32: *Fusivoluta capensis* (THIELE), DMNH 10123 (x 1.7)

Figure 33: *Fusivoluta anomala* (MARTENS), copy of original figure (x 1)

Figure 34: *Fusivoluta decussata* BARNARD, copy of original figure (x 3)



Figure 23



Figure 24



Figure 25



Figure 26



Figure 27



Figure 28



Figure 29



Figure 30



Figure 31



Figure 32



Figure 33

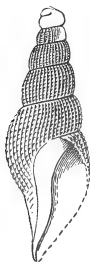


Figure 34



Aperture elongate-acuminate; anterior canal straight, rather short, moderately broad. Columella slightly sinuous, without trace of folds, and with a sharply limited yellowish-pink glaze over the parietal wall. Operculum half the size of aperture, elongately ovate, somewhat unguiculate; nucleus terminal, dark brown.

Specimens Examined: Holotype (DNMH 12833) and two paratypes (MCZ 264225, USNM 686370): off João Belo, District Gaza, Mozambique in 240 fathoms; two paratypes (DMNH 19305): 80 km E of Inhaca Island, District Lourenço Marques, Mozambique; paratype (DMNH 19307): 92 km E of Inhaca Island.

Measurements (in mm)

	aperture			locality
	length	width	length	
Holotype	96.7	31.3	47.6	Off João Belo
Paratype	98.3	32.9	49.9	Off João Belo
Paratype	80.1	28.1	40.6	Off João Belo
Paratype	79.8	27.1	39.0	92 km E of Inhaca
Paratype	75.6	26.9	40.2	80 km E of Inhaca
Paratype	74.5	25.7	38.7	80 km E of Inhaca

Remarks: This species is closest in general size and shape to *Fusivoluta barnardi* REHDER, differing markedly, however, in the stronger sculpture, different protoconch, and in the color of the shell. *Fusivoluta blazei* differs from *F. clarkei* in the lack of spiral sculpture on the later whorls (except for lirae on the base of the body whorl) and in possessing a smooth bulbous protoconch of 2½ whorls (Plate 42, Figure 31).

The two paratypes from off João Belo, sent originally by C. S. Weaver to Dr. Ruth Turner, contained the soft parts, which, however, were poorly preserved. Dr. Turner was able, nevertheless, to obtain some anatomical information, which she has kindly permitted me to include in this paper, as follows:

The siphon had a large left lobe but no real right lobe. The eyes are minute, black, and situated at the base of the broad flat tentacles. The anatomy of the digestive tract is very close to that figured for the Volutinae (CLENCH & TURNER, 1964, p. 136, pl. 82). The racemose salivary glands had nearly disintegrated, and the tubular glands were so free of them that it is possible that their condition resembles that in the Volutinae. It is, however, equally possible that they were only loosely connected with the racemose glands as in the Zidoninae, and became "easily un wound" (CLENCH & TURNER, 1964, p. 134) due to

the disintegration of the soft parts. Leiblein's gland was as in the Volutinae with an enlarged distal end. Both specimens were males, with very large intro-mittant organs.

The radula resembles that described and figured for *Fusivoluta pyrrhostoma* (WATSON, 1882) (BARNARD, 1959, p. 30, fig. 9b, 9c) except that the basal edge is more broadly emarginate, similar to the radula of *Callio-tectum vernicosum* (DALL, 1890) (PILSBRY & OLSSON, 1954, pl. 3, fig. 16).

Fusivoluta barnardi REHDER, spec. nov.

(Plate 40, Figure 9; Plate 43, Figures 40 to 43)

Fulguraria blazei BARNARD, 1963, p. 163 (not BARNARD, 1959)

Diagnosis: Shell rather large, solid, fusiform, with a somewhat bulbous, smooth protoconch of few whorls, early postnuclear whorls angulate, axially ribbed, and with fine spiral threads, which on the later whorls become very fine and obscure, giving a smooth appearance to penultimate and ultimate whorls. Outer lip somewhat effuse.

Distribution: Off the Natal coast, South Africa, generally in the vicinity of the mouth of the Tugela River, in 120 - 180 fathoms.

Description: Shell rather large, 105 - 117 mm in length, elongate fusiform, dull white in color when fresh, dead shells orange-yellow (stained by iron oxide?). Protoconch large, bulbous, consisting of 1 to 1½ smooth whorls; the 8 postnuclear whorls sculptured as follows: first whorl with slightly angulate periphery marked by axially elongate nodules, which are at first crowded, but become gradually more separated; following whorls begin to show spiral cords, at first below the periphery, and then appearing above and gradually becoming more numerous by intercalation. These fine spiral cords cross axial ribs of which the first few are obscure and somewhat distantly separated, but then become more pronounced, especially at the periphery, making these whorls subangulate. At about the beginning of the fourth whorl the axial ribs begin diminishing in strength and the whorls become moderately and evenly convex; with the fifth whorl ribs become very faint; on the last two whorls they have completely disappeared, the surface being marked only by irregular growth lines crossing the crowded, fine, unequal, spiral threads and rendering the latter somewhat irregular; on the penultimate whorl of the holotype these fine spiral threads number 62. The body whorl terminates in a moderately short attenuate canal, and the outer lip flares

out somewhat. The aperture is rather elongate, the columella straight, without folds, and the parietal wall is usually covered by a thin glaze.

Specimens Examined:

Holotype (DMNH 10751): Off Natal coast, trawled in 120 fathoms, June 1962.

Paratypes: (USNM 686300) off North Natal to South Zululand coast, trawled in 120 fathoms; (DMNH 10750): off mouth Tugela River, South Zululand, in 160 - 180 fathoms, July 1960.

Measurements (in mm)

		length	width	apert. length ^a
Holotype	(DMNH 10751)	115.2	34.6	52.9
Paratype	(USNM 686300)	93.4	32.3	45.2
Paratype	(DMNH 10750)	96.5 ^b	35.0	45.9

Remarks: This species is closest to *Fusivoluta clarkei* but can be readily separated from it by the bulbous protoconch, the finer, more numerous spiral threads, becoming obscure on the body whorl, the less prominent axial ribs, and the apparently different color of fresh shells. *Fusivoluta clarkei* occupies a more northerly geographic range than does *F. barnardi*.

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- Figures 35 & 36: *Fusivoluta blaisei* (BARNARD), Holotype SAM A3433 (x 2)
- Figure 37: *Fusivoluta clarkei* REHDER, spec. nov., Holotype DMNH 12833 (x 1)
- Figures 42 & 43: *Fusivoluta barnardi* REHDER, spec. nov., Paratype USNM 686300 (x 1)
- Figures 38 & 39: *Fusivoluta clarkei* REHDER, spec. nov., Paratype DMNH 19307 (x 1)
- Figures 40 & 41: *Fusivoluta barnardi* REHDER, spec. nov., Holotype DMNH 10751 (x 1)

Explanation of Plate 43

Figures 35 & 36: *Fusivoluta blaisei* (BARNARD), Holotype

SAM A3433 (x 2)

Figure 37: *Fusivoluta clarkei* REHDER, spec. nov., Holotype

DMNH 12833 (x 1)

Figures 42 & 43: *Fusivoluta barnardi* REHDER, spec. nov., Paratype

USNM 686300 (x 1)

Figures 38 & 39: *Fusivoluta clarkei* REHDER, spec. nov., Paratype

DMNH 19307 (x 1)

Figures 40 & 41: *Fusivoluta barnardi* REHDER, spec. nov., Holotype

DMNH 10751 (x 1)



Figure 35



Figure 36



Figure 37



Figure 38



Figure 39



Figure 40



Figure 41



Figure 42



Figure 43



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List of Type Specimens of Terebridae in the British Museum (Natural History)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

and Division of Mollusks, Smithsonian Institution, U. S. National Museum, Washington, D. C. 20560

DURING A RECENT VISIT to the British Museum (Natural History), London, I have examined and recorded the dimensions of all Terebridae types preserved in the type-collection of the British Museum. All the types present were photographed in colour, with the exception of 4 Carpenter types from Mazatlan, which have been dealt with recently by KEEN (1968).

It has been found in some instances that specimens marked in the collection as types or syntypes were in fact neither. Specimens have been selected as "types" which do not correspond with either the original author's stated dimensions or figure, if such was appended; usually larger or better preserved specimens have been selected as types possibly by Smith, Tomlin or some other worker. TOMLIN (1944) suggested that Cuming may have substituted better specimens at a later date and subsequent to the description of the species. My own observations show that such specimens have indeed been added at a later date and were glued to the same tablet as the original type or type series.

The isolation of unequivocal types depends firstly on the undoubted physical and possible presence of such types in the British Museum. If Deshayes for instance described a species from his own collection, we can expect the holotype to be in the École des Mines in Paris and not in the Cuming collection in London. Secondly, the types present must correspond as closely as possible with either the original description, the stated dimensions or the original figure. Only those types which meet the foregoing requirements have been listed as "holotypes." In a case where 2 or more specimens in a syntype series agree in dimensions with a fraction of a millimeter with the original measurements given for the "type," an appropriate lectotype has been selected. Such holotypes and lectotypes should be interpreted purely as units of refer-

ence representative of a species and not as units of natural populations.

HINDS (1844) stated his size in "lin." (= lines) for one particular specimen of a species he described. Since British naturalists used the "inch," "pollex" or "mm" as units of measure for mollusks, it is presumed that HINDS (*loc. cit.*) adopted the French "ligne" of continental authors, and popular with French malacologists at that time, due to the restoration period re-introduction. The French "ligne" is equivalent to 2.25 mm, and using this conversion factor, type specimens present in the type collection match the given dimensions far better than the one-tenth of an inch conversion factor adopted by KEEN (1966).

Some of the type specimens present in the type collection have been marked with an "x" in either the aperture of the shell or on the tablet next to the supposed holotype. It should be pointed out that some specimens have been wrongly marked as the type in a few instances. Specimens described by E. A. SMITH have a small spot of red wax attached to the type, in some cases in addition to an "x" mark in the aperture or on the tablet; we can presume that these have been marked in this way by Smith himself.

ACKNOWLEDGMENTS

I would like to express my appreciation to Dr. N. Tebbles, British Museum (Natural History), London, for having made the collection available for examination, and for the help and assistance extended by himself and his staff.

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LIST OF SPECIES

Species are arranged in alphabetical order for quick reference. The following abbreviations for publications and journals have been adopted in this paper:

- A. M. N. H. = Annals and Magazine of Natural History, London
 J. C. L. = Journal of Conchology, Leeds
 J. C. P. = Journal de Conchyliologie, Paris
 M. P. M. L. P. S. = Memoirs and Proceedings of the Manchester Literary and Philosophical Society
 P. M. S. L. = Proceedings of the Malacological Society of London
 P. Z. S. L. = Proceedings of the Zoological Society of London.

1. *aciculina*, *Terebra* – REEVE, 1860, Conch. Icon., plt. 23, fig. 121 b (non LAMARCK, 1822). Hab. ? Coll. Taylor. Size of REEVE's figure: 38.0 mm. Holotype: No. 74.12.11.298: 36.0 mm.
2. *acuminata*, *Terebra* – REEVE, 1860, Conch. Icon., plt. 26, sp. 143 (non BORSON, 1820; nec GRATELOUP, 1834). Hab. ? Coll. Cumming. Size of figure: 28.5 mm. Holotype: 29.5 mm (marked x near apex of shell on tablet). = *Hastula exacuminata* SACCO, 1891.
3. *acuta*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 100; plt. 4, figs. 4, 5. Hab.: les mers de Chine. Size: 57×7 mm (1857); 97×7 mm (1859). Coll. Cumming. Supposed holotype: 46.9 mm (marked x inside aperture). The dimension of 97 mm given by Deshayes in 1859 is certainly an error for 57 mm which was the largest specimen among the specimens examined by Deshayes. The specimen present in the collection is appreciably smaller. = *Terebra anilis* (RÖDING, 1798).
4. *adamsi*, *Terebra* – E. A. SMITH, 1873, A. M. N. H., 11: 264. Hab. Japan (A. ADAMS). Coll. Cumming. Size: 36×6½ mm. Holotype: 35.5 mm; paratypes: 33.6 mm and 21.8 mm.
5. *adansoni*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 291. Hab. Sénégal. Coll. Cumming and Deshayes. Size: 39×8 mm. There are 3 syntypes in the type collection: 32.6 mm, 32.5 mm and 31.8 mm, but these are appreciably smaller than the stated type, which is possibly in the Deshayes collection in the École des Mines in Paris. = *Terebra micans* HINDS, 1844.
6. *addita*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 293. Hab. La Terre de Van Diemen. Coll. Cumming. Size: 33×7 mm. Holotype: 32.3 mm.
7. *affinis*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 60. Hab. ? Coll. J. E. Gray. Size: 1¼" (= 44.5 mm); Var. a. *parva* 1¼" (= 31.7 mm); Var. b. *gracilior* 1" (= 25.4 mm). Holotype no. 74.11.10.17: 42.5 mm; var. a: 31.0 mm; var. b: 27.6 mm.
8. *africana*, *Terebra* – GRAY in GRIFFITH & PIDGEON, 1834, Moll. Reg. Anim. Cuv., plt. 23, fig. 5. Hab. ? Coll. J. E. Gray. Size of figure: 68.0 mm. Holotype no. 74.10.12.12: 67.4 mm (marked x inside aperture); syntype is 61.6 mm. = *Terebra variegata* GRAY, 1834.
9. *albida*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 63. Hab. ? Coll. J. E. Gray. Size: 1¼" (= 31.7 mm). Holotype no. 74.11.10.4: 34.3 mm.
10. *albocincta*, *Terebra* (*Myurella*) – CARPENTER, 1857. see KEEN, 1968, The Veliger 10: 428, plt. 58, fig. 70. = *Terebra variegata* GRAY, 1834.
11. *albomarginata*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 314. Hab. L'Australie. Coll. Cumming. Size: 44×8 mm. Holotype: 44.5 mm (marked x inside aperture); this shell is yellowish-orange in colour with a white sutural band, obsolete axial plicae and 4 spiral rows of deep pits on each whorl. There is another specimen in the same box measuring 39.6 mm, and the loose label says "Coll. Dr. Gray" – no. 74.10.12.14. This Gray specimen is identical in sculpture with the holotype of *Terebra albomarginata*, except that it is uniformly dark brown in colour, and is the *T. cumingii* of authors, not of DESHAYES, 1857.
12. *albozonata*, *Terebra* – E. A. SMITH, 1875, A. M. N. H., 15: 415 and 1877, A. M. N. H., 19: 226. Hab. Matoza Harbour, Japan (Commander St. John). Coll. J. G. Jeffreys. Size: 25×7 mm. Holotype, no. 73.8.6.9: 24.7 mm (spot of red wax on labial lip); paratype: 8.0 mm.
13. *ambrosia*, *Terebra* – MELVILL, 1912, P. M. S. L., 10: 250, plt. 11, fig. 10. Hab. Mekran coast, Charbar. Size: 16×4½ mm. Holotype no. 1912.9.17.38: 15.9 mm; Paratype no. 1912.9.17.39: 12.4 mm. = *Terebra exigua* DESHAYES, 1859.
14. *amoena*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 297. Hab. Les mers de la Chine. Coll. Cumming. Size: 24×6 mm. Holotype: 24.2 mm.
15. *andamanica*, *Terebra* – MELVILL & SYKES, 1898, P. M. S. L., 3: 41, plt. 3, fig. 3. Hab. Andaman Islands. Size: 47×9 mm and 35×7 mm. Only holotype present, no. 1895.4.30.2: 47.9 mm (marked x inside aperture). = *Terebra pertusa* BORN, 1778.
16. *anomala*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 62. Hab. ? Coll. J. E. Gray. Size: 1¼" (= 44.5 mm). Holotype: 42.6 mm (marked x near apex of the shell on tablet).
17. *antarctica*, *Abretia* – E. A. SMITH, 1873, A. M. N. H., 11: 270. Hab. Antarctic region ("New Zealand" on

- tablet). Coll. Justice Gillies. Size: $14 \times 4\frac{1}{2}$ mm. Holotype no. 80.7.2.5: 13.3 mm; plus 5 paratypes present in collection. = *Terebra tristis* DESHAYES, 1859.
18. *apicina*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 284. Hab. Singapore. Coll. Cuming. Size: 22×5 mm; Holotype: 22.7 mm; syntypes 21.2 mm and 18.8 mm.
 19. *apicitincta*, *Terebra* – SOWERBY, 1901, P. M. S. L., 4: 5, plt. 1, fig. 14. Hab. The Kowie. Size: 12.5×3 mm. Holotype no. 1900.5.22.42: 12.6 mm (marked x near apex of shell on tablet); paratypes no. 1900.5.22.43-44: 12.6 and 11.8 mm, respectively.
 20. *arabella*, *Terebra* – THIELE, 1925, Wiss. Erg. Deut. Tief. Exp. Valdiv., 17: 312, plt. 29, fig. 24. Hab. Sumatra. Ex coll. Berlin Museum. Three paratypes no. 1948.12.10.5-7.
 21. *archimedis*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 314. Hab. ? Size: 31×6 mm. Holotype: 32.7 mm; syntypes: 39.6 mm (this specimen is erroneously marked as the type with an x inside the aperture) and 20.5 mm. This is the *Terebra funiculata* of authors, not of HINDS, 1844.
 22. *areolata*, *Terebra* – ADAMS & REEVE, 1850, Voy. Samarang, p. 30, plt. 10, fig. 23 (non *Vertagus areolatus* LINK, 1807). Hab. China Seas ("Fiji Islands" on label). Size of figure: 36.0 mm. Three syntypes present, rather questionable ones at that, of which the largest measures 24.0 mm and is marked with x inside the aperture and near the apex of the shell on the tablet. These 3 specimens are the same species as *Terebra kilburni* R. D. BURCH, 1965.
 23. *argus*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 160 (nom. nov. pro *Terebra nebulosa* KIENER, 1838). Hab. Tahiti, Society Islands, Cuming; and Nukuhiva, Marquesas, Belcher. Size: none given. Lectotype no. 1968253: 88.7 mm; paralectotypes 81.6 mm and 74.1 mm.
 24. *armillata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 154. Hab. Between Panama and the Bay of Magdalena in Lower California, also Galapagos. Coll. Belcher and Cuming. Size: 22 lin. (= 49.5 mm). Holotype: 49.2 mm; syntypes: 43.3 mm and 43.1 mm.
 25. *aspera*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 154 (non Bosc, 1801). Hab. Panama, Monte Christi, St. Elena, west coast of America ("Punta St. Elena, West Colombia" on label). Coll. Cuming. Size: 23 lin. (= 51.8 mm). Holotype: 54.5 mm (marked x inside aperture); syntypes: 46.8 mm and 37.9 mm.
 26. *assimilis*, *Acus (Abretia)* – ANGAS, 1867, P. Z. S. L., p. 111, plt. 13, fig. 8. Hab. Dredged in Port Jackson. Coll. Angas. Size: $5\frac{1}{2} \times 1\frac{1}{2}$ lines (= 12.4×3.4 mm). Holotype no. 70.10.26.53: 11.7 mm; syntype: 10.2 mm. = *Terebra fertilis* HINDS, 1844.
 27. *australis*, *Terebra* – E. A. SMITH, 1873, A. M. N. H., 11: 264. Hab. Swan River, and Paterson's Bay, Torres Strait, North Australia (J. R. Elsey). Size: $55 \times 12\frac{1}{2}$ mm. Holotype: 54.4 mm.
 28. *bacillus*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 285. Hab. Iles Sandwich. Coll. Cuming. Size: 23×5 mm. Holotype: 22.9 mm; syntypes: 22.0 mm, 19.4 mm, 17.4 mm, and 17.0 mm.
 29. *ballina*, *Duplicaria* – HEDLEY, 1915, Proc. Linn. Soc. N. S. W., 39: 729, plt. 84, fig. 86. Hab. Trial Bay, N. S. W. Coll. Hedley. Paratype: 19.6 mm.
 30. *bathyrhaphe*, *Terebra (Myurella)* – E. A. SMITH, 1875, A. M. N. H., 15: 415 and 1877, A. M. N. H., 19: 226. Hab. Gulf of Yedo, Japan (Commander St. John). Coll. J. G. Jeffreys. Size: 25×5 mm. Holotype no. 73.8.6.10: 24.8 mm (spot of red wax on columella); syntypes: 21.7 mm, 20.0 mm, 17.0 mm, and 10.3 mm.
 31. *belcheri*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 267 (non *Terebra belcheri* PHILIPPI, 1851). Hab. Guayaquil, Ecuador. Coll. Belcher. Size: 39×8 mm. Holotype no. 44.6.7.77: 38.0 mm. = *Terebra guayaquilensis* E. A. SMITH, 1880.
 32. *bernardii*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 84, plt. 4, fig. 10. Hab. Les côtes orientales de l'Australie. (Moreton Bay on label). Coll. Cuming. Size: 58×14 mm. Holotype: 57.4 mm (marked x inside aperture); syntypes: 52.8 mm and 49.9 mm.
 33. *bicolor*, *Acus (Abretia)* – ANGAS, 1867, P. Z. S. L., p. 111, plt. 13, fig. 7. Hab. Dredged in Middle Harbour, Port Jackson. Coll. Angas. Size: 8×2 lines (= $18 \times 4\frac{1}{2}$ mm). Six syntypes: 15.0 mm, 15.0 mm, 14.3 mm, 13.4 mm, 12.8 mm, and 11.6 mm.
 34. *bifrons*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155. Hab. Japan; leg. Dr. Siebold. Coll. Cuming. Size: 23 lines (= 51.8 mm). Holotype no. 1968237: 51.0 mm (marked x inside aperture). There is another specimen present in the type collection 45.3 mm in length, which is not a type, as HINDS (1844) mentioned the specimen he described to be unique.
 35. *bipartita*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 284 (non SOWERBY, 1850). Hab. Iles Sandwich. Coll. Cuming. Size: 22×5 mm. Holotype: 22.3 mm; syntype: 19.1 mm. = *Hastula albula* (MENKE, 1843).
 36. *blanda*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 298. Hab. Les mers du Japon. Size: 30×8 mm. Holotype: 29.9 mm.
 37. *booleyii*, *Terebra crenulata* var. – MELVILL & SYKES, 1898, P. M. S. L., 3: 44, plt. 3, fig. 5. Hab. Andaman Islands. Size: not given. Holotype: 68.7 mm. = *Terebra crenulata* (LINNAEUS, 1758).
 38. *bourguignati*, *Terebra* – DESHAYES, 1859, P. Z. S. L.,

- p. 288. Hab. Les mers de la Chine. Coll. Cuming and Deshayes. ("coll. Fortune" on label). Size: 19×4 mm. Paratype only present, measuring 14.5 mm; holotype probably in École des Mines in Paris. = *Terebra plumbea* QUOY & GAIMARD, 1833.
39. *brasiliensis*, *Abretia* – E. A. SMITH, 1873, A. M. N. H., 11: 271. Hab. Botafogo Bay, Rio de Janeiro (Macgillivray, H. M. S. *Rattlesnake*). Size: 11×3 mm. Holotype no. 60.5.2.28: 10.3 mm; syntypes: 9.0 mm and 7.5 mm.
40. *brazieri*, *Terebra* (*Hastula*) – ANGAS, 1871, P. Z. S. L., p. 16, plt. 1, fig. 15. Hab. Brisbane Water, New South Wales; Brazil. Size: $1 \frac{1}{2}$ lines \times 3 lines (= 29.9×6.8 mm). Holotype no. 71.7.5.15: 27.8 mm; syntypes: 26.2 mm, 25.8 mm, and 23.2 mm.
41. *brevicula*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 296. Hab. La Terre de Van Diemen. Coll. Cuming. Size: 37×8 mm. Two specimens present: 25.6 mm (erroneously marked x inside aperture) and 21.6 mm, but neither corresponds with Deshayes' given size.
42. *bruguieri*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 297 (nom. nov. pro *Terebra hindii* DESHAYES, 1857). Hab. La Chine. Coll. Cuming. Size: 42×9 mm. Holotype: 39.8 mm (marked x inside aperture); syntype: 37.5 mm. = *Terebra conspersa* HINDS, 1844.
43. *buccinum*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 92, plt. 5, fig. 12. Hab. l'Australie, côte orientale. Coll. Cuming. Size: 37×10 mm. Lectotype: 37.1 mm; syntypes: 36.9 mm, 36.0 mm, and 36.0 mm. This is the same species as *Bullia turrita* GRAY, 1839.
44. *caelata*, *Terebra* – ADAMS & REEVE, 1850, Voy. Samarang, p. 30, plt. 10, fig. 22. Hab. China Seas. Size of figure: 40.6 mm. Holotype: 41.0 mm. = *Terebra fenestrata* HINDS, 1844.
45. *caledonica*, *Terebra* – SOWERBY, 1909, P. M. S. L., 8: 198, text fig. Hab. Isle of Pines, New Caledonia. Size: 47×11 mm. Holotype no. 1909.10.19.103: 46.8 mm.
46. *caliginosa*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 287. Hab. Isles Philippines. Coll. Cuming. Size: 30×6 mm. Holotype: 29.7 mm.
47. *capensis*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 269. Hab. Port Elizabeth, Cape of Good Hope. Size: 19×5 mm. Holotype: 17.0 mm; syntypes: 14.1 mm, 12.7 mm, 11.6 mm, 9.2 mm, and 9.0 mm.
48. *casta*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 156. Hab. Ilo-Ilo, Island of Panay, Philippines. Size: 13 lin. (= 29.2 mm). Holotype no. 1968242: 29.0 mm; syntypes: 38.2 mm, 33.3 mm, 32.5 mm, and 30.3 mm. = *Hastula alba* (MENKE, 1843).
49. *celidonota*, *Terebra* – MELVILL & SYKES, 1898, P. M. S. L., 3: 42, plt. 3, fig. 2. Hab. Andaman Islands. Size: 15×3 mm. Holotype no. 98.4.30.5: 15.0 mm; paratype no. 98.4.30.6: 13.2 mm. = *Hastula strigilata* (LINNAEUS, 1758).
50. *cernohorskyi*, *Hastula* (*Punctoterebra*) – R. D. BURCH, 1965, The Veliger 7: 244, plt. 31, fig. 3. Hab. Natadola, Fiji Islands. Coll. W. O. Cernohorsky. Paratype no. 1965142: 59.8 mm. Rather similar to *Hastula laurina* (HINDS, 1844).
51. *cinctella*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 305. Hab. L'embouchure de l'Indus. Coll. Cuming. Size: 29×6 mm. Holotype: 27.8 mm; syntypes: 31.0 mm (erroneously marked x inside aperture), and 26.9 mm.
52. *circinata*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 99, plt. 4, figs. 6, 7. Hab. les mers de Chine. Coll. Cuming. Size: 42×6 mm. Holotype: 41.3 mm (marked x inside aperture). = *Terebra anilis* (RÖDING, 1798).
53. *circumcincta*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 77, plt. 3, fig. 9. Hab. la mer Rouge (Red Sea and Port Curtis on label). Coll. Cuming (ex Stutchbury). Size: 40×8 mm. Holotype: 38.0 mm (marked x inside aperture); probable syntype: 50.1 mm.
54. *cognata*, *Terebra* (*Myurella*) – E. A. SMITH, 1877, A. M. N. H., 19: 229. Hab. Persian Gulf (Colonel Pelly). Size: $14 \times 3 \frac{1}{2}$ mm. Coll. R. MacAndrew. Holotype: 73.7.5.7: 13.3 mm (spot of red wax on whorl above aperture and marked x near apex of shell on tablet); syntypes: 6.1 mm, and 5.6 mm.
55. *columellaris*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 151. Hab. ? ("Tahiti?" on label). Coll. Cuming. Size: 19 lin. (= 42.8 mm). Holotype no. 1968228: 43.0 mm; syntypes: 44.0 mm (erroneously marked x in aperture), and 40.8 mm.
56. *concolor*, *Terebra* – E. A. SMITH, 1873, A. M. N. H., 11: 265. Hab. ? Size: 22×6 mm. Holotype no. 1858.5.12.252: 22.0 mm. This appears to be a worn specimen of *Duplicaria jukesii* (DESHAYES, 1857).
57. *consobrina*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 72, plt. 3, fig. 3. Hab. la mer Rouge ("Massau, Red Sea" on label). Coll. Cuming. Size: 93×14 mm (93×12 mm in 1859). Holotype: 89.3 mm; syntypes 88.5 mm, and 84.0 mm.
58. *consors*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 150. Hab. Tahiti, Society Islands. Coll. Cuming. Size: 31 lin. (= 69.8 mm). Holotype no. 1968173: 70.9 mm; syntypes: 53.2 mm, and 46.8 mm.
59. *conspersa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 153. Hab. Catbalonga, island of Samar, Philippines. Coll. Cuming. Size: 10 lin. (= 22.5 mm). Holotype: 23.5 mm; syntype: 19.5 mm.
60. *continua*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 286. Hab. ? ("Japan" on label). Coll. Cuming and Deshayes. Size: 31×7 mm. Holotype: 32.5 mm.

61. *contracta*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 268. Hab. ? Coll. Belcher. Size: $17 \times 3\frac{1}{2}$ mm. Holotype: 16.0 mm.
62. *copula*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 151. Hab. Guinea. Coll. Cuming. Size: 17 lin. (= 38.3 mm). Holotype no. 1968227: 39.4 mm; syntypes: 33.8 mm, and 29.8 mm.
63. *crenifera*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 298. Hab. les mers de la Chine. Coll. Cuming. Size: 30×6 mm. Holotype: 29.8 mm. This species is occasionally synonymized with *T. cingulifera* LAMARCK, 1822, but it is not that species; the locality itself is suspect. The type of *T. crenifera* bears a great resemblance to *T. ligyrus* PILSBRY & LOWE, 1932: the axial ribs are well defined and slender and form slender nodes at the sutures; the interstices are very broad and there are traces of an orange-brown colour on the shell and in the interstices of the sutural nodes.
64. *cumingii*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 66, plt. 3, fig. 1. Hab. les mers de Chine. Coll. Cuming. Size: According to DESHAYES (1857), he examined 3 examples, the largest of which measured 95×12 mm. Holotype: 93.0 mm; only one syntype: 58.3 mm.
65. *cuspidata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 157 (non Bosc, 1801). Hab. Cape Coast, Africa. Coll. Cuming. Size: 13 lin. (= 29.3 mm). Holotype no. 1968247: 29.4 mm; syntypes: 29.9 mm, and 27.7 mm. = *Hastula traili* (DESHAYES, 1859).
67. *delicatula*, *Terebra* – PRESTON, ? Hab. Martinique on label. Holotype no. 1911.8.22.273: 9.0 mm. I was not able to trace the reference for this species.
66. *decorata*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 75, plt. 4, fig. 13. Hab. Pidang (île Sumatra). Capt. Martin. Coll. Cuming. Size: 28×6 mm. Holotype: 27.0 mm. There is another specimen in the type collection, 44.0 mm in length, which was collected by Lt. Col. Wilmer at Aden, and is not a type. (= "*T. tessellata* GRAY, 1834", on label).
68. *dillwyni*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 279. Hab. les mers du Japon. Coll. Cuming and Deshayes. Size: 40×9 mm. Holotype: 38.9 mm; juvenile syntype: 12.6 mm.
69. *diversa*, *Terebra* (*Abretia*) – E. A. SMITH, 1901, J. C. L., 10: 115, plt. 1, fig. 6. Hab. Umzinto, Natal (H. Burnup). (On label is written "Turton", not Burnup). Size: 27×5 mm. Questionable syntypes: 22.5 mm, 17.6 mm, and 17.6 mm. These syntypes appear to be the same species as *Hastula parva* (BAIRD in BRENCHEY, 1873), except that on the latter species the sutural brown spots are set closer.
70. *edgarii*, *Terebra* – MELVILL, 1898, M. P. M. L. P. S., 42: 8, plt. 2, fig. 12. Hab. Karachi. Size: $19 \times 4\frac{1}{2}$ mm. Holotype no. 98.7.5.32: 19.0 mm – juvenile specimen.
71. *elata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 156. Hab. Bay of Montijo, west coast of America. Coll. Cuming. Size: 12 lin. (= 27.0 mm). Holotype no. 1968-240: 26.6 mm; syntypes: 24.9 mm, and 24.3 mm.
72. *evoluta*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 292. Hab. Japon. Coll. Cuming. Size: 50×11 mm. Probable holotype: 56.2 mm; syntypes: 29.6 mm, 22.3 mm, and 21.7 mm.
73. *exigua*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 301. Hab. La côte orientale d'Australie. Coll. Cuming. Size: $19 \times 3\frac{1}{2}$ mm. Holotype: 20.8 mm; there is another 14.6 mm specimen in the type collection ex Wilmer from the Andaman Islands, which is not a type.
74. *fatua*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 150. Hab. Statu. Christopher, West Indies (Mr. Miller, 1799). Coll. Cuming. Size: 34 lin. (= 76.5 mm). Holotype no. 1968175: 74.9 mm (marked x inside aperture); syntype: 62.7 mm.
75. *fenestrata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 153. Hab. San Nicholas, Island of Zebu, Philippines. Coll. Cuming. Size: 15 lin. (= 33.7 mm). Holotype no. 1968233: 32.7 mm; syntypes: 31.3 mm and 30.0 mm.
76. *festiva*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 74, plt. 3, fig. 4. Hab. le Sénégal. Coll. Cuming. Size: 35×8 mm (39 \times 8 mm in 1859). Holotype: 35.5 mm; syntypes: 36.7 mm (wrongly marked x in aperture), and 32.8 mm. = *Terebra senegalensis* LAMARCK, 1822.
77. *fictilis*, *Terebra* – HINDS in SOWERBY, 1844, Thes. Conch. I: 183, plt. 45, figs. 109, 110. Hab. Australia. Coll. Cuming. Size of figure: $14\frac{1}{2}$ mm. Holotype: 14.8 mm; syntypes: 15.9 mm, and 12.6 mm.
78. *fijsiens*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 266. Hab. Ovalau, Fiji Islands (J. McGillivray on label). Size: 21×4 mm. Holotype no. 1856.10.278: 19.8 mm.
79. *fimbriata*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 71, plt. 5, fig. 1. Hab. ? (Coll. Cuming and Deshayes in 1859). Size: 88×19 mm. Paratype: 71.7 mm (holotype probably in École des Mines in Paris). = *Terebra crenulata* (LINNAEUS, 1758).
80. *flava*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 60. Hab. ? Size: 1" (= 25.4 mm). Holotype: 23.4 mm (marked x inside aperture). = *Terebra lutescens* E. A. SMITH, 1873.

81. *flavescens*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 299. Hab. Les îles Sandwich. Coll. Cumming ("Mr. Pease" on label). Size: 45×9 mm. Holotype: 44.6 mm.
82. *formosa*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 65, plt. 3, fig. 6. Hab. la mer de Panama. Coll. Cumming. Size: 72×13 mm. Holotype: 70.9 mm.
83. *fortunei*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 79, plt. 4, fig. 1. Hab. les mers de Chine. Coll. Cumming. Size: 69×9 mm. Holotype: 68.1 mm.
84. *funiculata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 153. Hab. ? ("Marquesas" on label). Coll. Belcher and Cumming. Size: 23 lin. (= 51.7 mm). Holotype: 50.3 mm (marked x inside aperture); syntype: 46.5 mm. (*Terebra langfordi* PILSBRY, 1921 is a synonym).
85. *fuscobasis*, *Terebra* (*Myurella*) – E. A. SMITH, 1877, A. M. N. H., 19: 227. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: $11 \times 3\frac{3}{4}$ mm. Holotype: 11.3 mm (spot of red wax on whorl above aperture); syntype: 9.2 mm.
86. *fuscinicta*, *Terebra* (*Myurella*) – E. A. SMITH, 1877, A. M. N. H., 19: 228. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: 8×2 mm. Holotype no. 73.7.5.3: 7.7 mm (spot of red wax on whorl above aperture); syntypes: 6.3 mm, 5.3 mm, 4.9 mm, and 3.8 mm.
87. *geminata*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 296. Hab. Cap Natal. Coll. Cumming. Size: 30×7 mm. Holotype: 30.3 mm (marked x inside aperture); syntype: 26.4 mm. = *Terebra spectabilis* HINDS, 1844.
88. *glabra*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 101, plt. 5, fig. 13. Hab. les mers de Chine. Coll. Deshayes. Size: 70×13 mm. The specimen present in the Cumming Collection and measuring 43.3 mm in length is not a type; the holotype is probably in the École des Mines in Paris. The specimen present is a worn *Terebra consors* HINDS, 1844.
89. *glauca*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155. Hab. ? Coll. Cumming. Unique! Size: 14 lin. (= $31\frac{1}{2}$ mm). Probable holotype: 27.8 mm. There is another specimen present in the type collection, measuring 18.3 mm and from the Seychelles; since Cumming's specimen was said to be unique, the Seychelles specimen is a later addition.
90. *gotoensis*, *Terebra* – E. A. SMITH, 1879, P. Z. S. L., p. 183, plt. 19, figs. 1, 1a. Hab. Goto Island, Japan. Coll. J. G. Jeffreys. Size: 25×5 mm (fig. 1); variety: $29 \times 4\frac{3}{4}$ mm (fig. 1a). Holotype no. 78.11.7.18: 25.1 mm (spot of red wax on whorl above aperture); paratype of variety 29.3 mm; a third syntype: 16.4 mm. = *Hastula melanacme* (E. A. SMITH, 1877).
91. *gouldii*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 89, plt. 5, fig. 2. Hab. les îles Sandwich. Coll. Cumming and Deshayes. Size: 70×18 mm. Paratypes: 61.6 mm (wrongly marked x inside aperture), and 59.2 mm. Holotype is probably in the École des Mines in Paris.
92. *gracilis*, *Terebra* – REEVE, 1860, Conch. Icon., plt. 24, spec. 131 (non LEA, 1833; nec GRAY, 1834). Hab. Africa. Size of figure: 21.6 mm. Holotype no. 74.10.29.2: 22.0 mm. ("Coll. J. E. Gray" on loose label). According to SMITH (1877), *T. gracilis* REEVE is not the *T. gracilis* of GRAY; he points out that *T. gracilis* GRAY was mounted on the same tablet as *T. gracilis* REEVE. This would account for the "Coll. J. E. Gray" on the loose label. On the reverse side of the tablet on which the specimen of *T. gracilis* REEVE is presently mounted, is the following note: "this specimen is figured by Reeve as the type of *gracilis*. For the true type see another tablet." No such tablet with GRAY's *T. gracilis* could be traced. REEVE's *T. gracilis* is a small specimen of *T. spectabilis* HINDS, 1844, with fewer ribs per whorl.
93. *granulosa*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 268 (non *Terebra granulosa* LAMARCK, 1822). Hab. Japan (A. Adams). Coll. Cumming. Size: 26×6 mm. Holotype: 24.6 mm (marked x next to specimen on tablet); syntypes: 21.8 mm, and 18.2 mm. = *Terebra pustulosa* E. A. SMITH, 1879.
94. *grayi*, *Terebra* – E. A. SMITH, 1877, A. M. N. H., 19: 227 (nom. nov. pro *Terebra gracilis* GRAY, 1834). No types present in the type collection.
95. *guayaquilensis*, *Terebra* – E. A. SMITH, 1880, P. Z. S. L., p. 481 (nom. nov. pro *Myurella belcheri* E. A. SMITH, 1873 – non *Terebra belcheri* PHILIPPI, 1851). For types see under *Myurella belcheri* E. A. SMITH; this appears to be an earlier name for *Terebra montijoensis* PILSBRY & LOWE, 1932.
96. *helichrysus*, *Terebra* – MELVILL & STANDEN, 1903, A. M. N. H., 12: 310, plt. 22, fig. 14. Hab. Persian Gulf, Mussandan. Size: 24×5 mm. Holotype no. 1903.12.15.117: $24\frac{1}{2}$ mm; paratype no. 1903.12.15.118: 15.3 mm.
97. *hindsii*, *Terebra* (*Myurella*) – CARPENTER, 1857 – see KEEN, 1968, p. 428, plt. 58, figs. 71a-b. = *Terebra variegata* GRAY, 1834.
98. *hindsii*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 81, plt. 5, fig. 5 (non CARPENTER, 1857). Hab. les mers de Chine. Coll. Cumming. Size: 42×9 mm. Only one specimen present in the type collection which measures 27.6 mm; it is a worn *T. conspersa* HINDS, 1844.
99. *incolor*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 283. Hab. îles Philippines. Coll. Cumming. Size: 34×8 mm. Holotype: 33.4 mm. = *Hastula alba* (MENKE, 1834).

100. *incomparabilis*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 307. Hab. Panama. Coll. Cuming. Size: 85×13 mm. Holotype: 84.6 mm; there is a slightly shouldered ridge in the centre of each whorl and the 2 spiral rows of spots are equal sized. = *Terebra lingualis* HINDS, 1844.
101. *inconstans*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 156. Hab. Sandwich Islands. Coll. Cuming. Size: 16 lin. (= 36.0 mm). Lectotype no. 1968243: 33.2 mm; syntypes: 33.1 mm, and 32.6 mm.
102. *insalli*, *Terebra* (*Triplostephanus*) – BRATCHER & BURCH, 1967, The Veliger, 10: 7, plt. 2, figs. 1-3. Gulf of Akabar (sic). Paratype: 52.4×7.9 mm.
103. *insignis*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 70, plt. 3, fig. 2. Hab. Panama. Size: 78×15 mm. Holotype: 77.0 mm; another specimen, possibly added later, 118.7 mm. = *T. lingualis* HINDS, 1844.
104. *interlineata*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 277. Hab. Les Îles Sandwich. Coll. Cuming. Size: 60.0 mm. Holotype: 61.2 mm, = juvenile specimen of *Terebra crenulata* (LINNAEUS, 1758).
105. *intertincta*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155. Hab. Gambia. Coll. Cuming and Saul. Size: 20 lin. (= 45.0 mm). Holotype no. 1968235: 44.1 mm; syntypes: 42.7 mm, and 40.4 mm (this specimen is erroneously marked x inside aperture). The locality indication is obviously erroneous; the species resembles in form, colour and sculpture the species *T. armillata* HINDS, 1844. The figure of *T. intertincta* in KEEN (1958) is dissimilar to the type, which has vertically concave whorls.
106. *japonica*, *Terebra* – E. A. SMITH, 1873, A. M. N. H., 11: 265. Hab. Japan (A. ADAMS). Size: 32×7 mm. Holotype: 31.4 mm (marked x inside aperture); syntypes: 29.3 mm, and 26.8 mm.
107. *jeffreysii*, *Terebra* – E. A. SMITH, 1879, P. Z. S. L., p. 184, plt. 19, fig. 2. Hab. Station 20 & 21, Japan. Size: 25×5 mm. Holotype no. 78.10.164: 25.0 mm (spot of red was on body whorl); syntypes: 22.5 mm, 21.0 mm, and 13.2 mm.
108. *jenningsi*, *Terebra* (*Triplostephanus*) – R. D. BURCH, 1965, The Veliger, 7: 248, plt. 31, fig. 9. Hab. Namotu Island, Fiji Islands. Coll. W. Cernohorsky. Paratype no. 19655143: 47.8 mm.
109. *jukesii*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 95, plt. 6, fig. 9. Hab. Port Essington. Coll. Cuming. Size: 33×8 mm. Holotype: 32.8 mm; syntype: 34.2 mm (erroneously marked x inside aperture).
110. *kienneri*, *Terebra* – DESHAYES, 1859, P. Z. S. L., pp. 292, 294. Hab. La Terre de Van Diemen. ("Tasmania" on label). Coll. Cuming and Paris Museum. Size: 22×6 mm. Holotype: 21.2 mm; syntype: 19.1 mm.
111. *kilburni*, *Terebra* (*Decorihastula*) – R. D. BURCH, 1965, The Veliger, 7: 249, plt. 31, fig. 8. Hab. Off Wading Island, Fiji Islands. Coll. W. Cernohorsky. Paratype no. 1965141: 16.3 mm.
112. *knockeri*, *Terebra* – E. A. SMITH, 1871, P. Z. S. L., p. 730, plt. 75, fig. 7. Hab. Whydah [West Africa]. Size: 20×4 mm. Lectotype no. 70.1.3.47: 18.9 mm; syntypes: 18.6 mm, 14.9 mm, 14.5 mm, and 13.8 mm. = *Hastula modesta* (DESHAYES, 1859).
113. *knorrii*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 59. Hab. ? Size: $2\frac{1}{2} \times \frac{1}{2}$ " (= $6\frac{1}{2} \times 12.7$ mm). Holotype: 62.7 mm. = *T. chlorata* LAMARCK, 1822.
114. *lactea*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 285. Hab. Îles Sandwich ("Vasigapatam, Dr. Traill" on label). Coll. Cuming and Deshayes. Size: 21×4 mm. Probable holotype: 19.6 mm; syntypes: 18.2 mm, and 16.0 mm. = *Hastula bacillus* (DESHAYES, 1859).
115. *laevigata*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 61. Hab. ? Size: $1\frac{1}{4}$ " (= 31.7 mm). Holotype no. 74.11.10.9: 28.0 mm; syntype: 21.7 mm.
116. *laevis*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 61. Hab. ? Size: $1\frac{1}{4}$ " (= 31.7 mm). Probable holotype no. 74.11.10.10: 34.3 mm. = *T. cingulifera* LAMARCK, 1822.
117. *larvaeformis*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155. Hab. St. Elena, Monte Christi, west coast of America ("Punta St. Elena, West Colombia" on label). Coll. Cuming. Size: 23 lin. (= 51.7 mm). Holotype no. 1968239: 50.7 mm; syntypes: 37.3 mm, and 31.7 mm.
118. *laurina*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 152. Hab. Western Africa. Coll. Cuming. Size: 32 lin. (= 72.0 mm). Holotype no. 1968229: 67.6 mm; syntype: 63.0 mm.
119. *lepada*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 158. Hab. Guinea. Coll. Cuming. Size: 10 lin. (= 22.3 mm). Holotype: 23.0 mm; syntypes: $2\frac{1}{2}$ mm, and 21.9 mm. = *Hastula strigilata* (LINNAEUS, 1758).
120. *ligata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 153. Hab. Marquesas. Coll. E. Belcher. Size: $15\frac{1}{2}$ lin. (= 34.9 mm). Probable holotype: 31.1 mm (juv. specimen).
121. *lightfooti*, *Terebra* (*Abretia*) – E. A. SMITH, 1899, J. C. L., 9: 247, plt. 5, fig. 1. Hab. Table Bay (Lightfoot). Coll. J. H. Ponsonby. Size: $19\frac{1}{2} \times 6$ mm. Holotype no. 99.9.9.2: 19.5 mm.
122. *lignea*, *Terebra* – REEVE, 1860, Conch. Icon., plt. 7, spec. 25 (nom. nov. pro *T. castanea* HINDS, 1844

- non KIENER, 1838). Hab. China; Fortune. Coll. Cuming. Size of figure: 63.2 mm. Holotype: 63.0 mm; syntypes: 62.4 mm, and 57.2 mm. = *T. badia* DESHAYES, 1859.
123. *lima*, *Terebra* — DESHAYES, 1857, J. C. P., 6: 69, plt. 4, fig. 2. Hab. les mers de Chine. Size: 78×11 mm. Holotype: $76\frac{1}{2}$ mm.
124. *lingualis*, *Terebra* — HINDS, 1844, P. Z. S. L., p. 153. Hab. Gulf of Papagayo, Bay of Montejo, west coast of America. Coll. Cuming. Size: 30 lin. (= $67\frac{1}{2}$ mm). Holotype no. 1968232: 68.1 mm; syntypes: 73.3 mm, and 57.2 mm. The specimen figured by CAMPBELL (1962) as the "type" of *T. lingualis* was the 73.3 mm syntype.
125. *livida*, *Terebra* — REEVE, 1860, Conch. Icon., plt. 22, spec. 116. Hab. Philippine Islands. Coll. Taylor. Size of figure: 41.8 mm. Holotype no. 74.12.11.299: 38.4 mm.
126. *loisae*, *Terebra* — E. A. SMITH, 1903, P. M. S. L., 5: 360, plt. 15, fig. 1. Hab. Umkomaas, Natal (Burnup). Coll. J. H. Ponsoby. Size: 30×6 mm. Holotype no. 1901.9.22.81: 28.4 mm; there are another 2 specimens present in the type collection which are not type material.
127. *longiscata*, *Terebra* — DESHAYES, 1859, P. Z. S. L., p. 294. Hab. Les Isles Philippines. Coll. Cuming. Size: 29×9 mm. There is one specimen in the type collection which is most probably the holotype and measures 24.4×4.8 mm. Deshayes' stated dimensions are obviously an error, since the given width in relation to the total length is out of proportion for such a slender species of *Terebra*.
128. *luctuosa*, *Terebra* — HINDS, 1844, P. Z. S. L., p. 157. Hab. Gulf of Nicoya, Puerto Portrero, west coast of America. Coll. Cuming and Belcher. Size: 17 lin. (= 38.3 mm). Holotype no. 1968246: 38.4 mm; syntypes: 40.6 mm, and 33.0 mm. The types are not smooth, but have fine slender axial ribs.
129. *lutescens*, *Terebra* — E. A. SMITH, 1873, A. M. N. H., 11: 264 (nom. nov. pro *T. flava* GRAY, 1834). For types see under *Terebra flava* GRAY, 1834.
130. *macandrewi*, *Terebra* (*Myurella*) — E. A. SMITH, 1877, A. M. N. H., 19: 228. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: $13\frac{1}{2} \times 4$ mm. Holotype no. 73.7.5.5: 13.4 mm (spot of red wax on whorl above aperture); syntype: 11.2 mm.
131. *macgillivrayi*, *Myurella* — E. A. SMITH, 1873, A. M. N. H., 11: 267. Hab. Brunei Island, south coast of New Guinea (J. MacGillivray, H. M. S. *Rattlesnake*). Size: 22×5 mm. Holotype no. 56.12.8.93: 21.8 mm.
132. *mamillata*, *Terebra* (*Myurella*) — WATSON, 1886, Voy. *Challenger*, Zool., 15: 381, plt. 16, fig. 1. Hab. Station 204 A or B, Philippines. Size: 1.35×0.25 inches (= 34.3 mm). Holotype no. 87.2.9.1159: 33.7 mm; paratype no. 87.2.9.1160: 29.6 mm.
133. *marginata*, *Terebra* — DESHAYES, 1857, J. C. P., 6: 86, plt. 4, fig. 8. Hab. L'embouchure de la Gambie. Coll. Cuming. Size: 34×8 mm. Holotype: 34.0 mm (marked x inside aperture); syntype: 29.6 mm. The locality indication of Gambia appears to be erroneous, since the types are coarsely sculptured *T. armillata* HINDS, 1844.
134. *mariesi*, *Terebra* — E. A. SMITH, 1880, P. Z. S. L., p. 480, plt. 48, fig. 5. Hab. Japan (Mr. Maries). Size: 45×7 mm. Holotype no. 1880.3.1.94: 43.0 mm (spot of red wax on whorl above aperture); syntype: 40.6 mm.
135. *marmorata*, *Terebra* — DESHAYES, 1859, P. Z. S. L., p. 279. Hab. Moreton Bay (there is also a label present bearing the locality "Port Curtis, ex Stutchbury"). Coll. Cuming. Size: 41×8 mm. Holotype: $40\frac{1}{2}$ mm.
136. *melanace*, *Terebra* — E. A. SMITH, 1875, A. M. N. H., 15: 415, and 1877, A. M. N. H., 19: 224. Hab. Cape Sima, Japan (Commander St. John). Coll. J. G. Jeffreys. Size: 17×4 mm (juvenile specimen). Holotype no. 73.8.6.11: 17.8 mm (spot of red wax on second whorl above aperture). There are two other specimens in the type collection, no. 1900.2.13.58.7: 23.2 mm, and 11.8 mm, which are later additions since SMITH (1877) had only 1 juvenile specimen on hand at the time of description.
137. *micans*, *Terebra* — HINDS, 1844, P. Z. S. L., p. 157. Hab. ? ("Cape Palmas, West Africa" on label). Coll. Cuming. Size: 13 lin. (= 29.3 mm). Holotype no. 1968248: 30.4 mm; syntypes: 23.1 mm, and 21.8 mm.
138. *miranda*, *Myurella* — E. A. SMITH, 1873, A. M. N. H., 11: 267. Hab. Malacca. Coll. Cuming. Holotype: 24.7 mm; syntype: 20.8 mm. The locality is suspect, since the types appear to be faded specimens of the West American *radula-aspera* group of species.
139. *modesta*, *Terebra* — DESHAYES, 1859, P. Z. S. L., p. 288. Hab. L'embouchure de l'Indus. Coll. Cuming. Size: 22×4 mm. Holotype: 21.6 mm; syntype: 20.6 mm (on label is written "= *T. matheroniana* DESHAYES, 1859").
140. *morbida*, *Terebra* — REEVE, 1860, Conch. Icon., plt. 24, spec. 133. Hab. ? Coll. Taylor. Size of figure: 13.8 mm. Holotype no. 79.2.26.25: 14.1 mm.
141. *nana*, *Terebra* — DESHAYES, 1859, P. Z. S. L., p. 291. Hab. L'embouchure de l'Indus. Coll. Cuming. Size: $10 \times 2\frac{1}{2}$ mm. Holotype: 9.9 mm.

142. *nassoides*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 158. Hab. ? Coll. Cuming. Size: 6 lin. (= 13.5 mm). Lectotype no. 1968251: 13.8 mm; syntypes: 15.5 mm, and 13.9 mm. This appears to be the same species as *T. bridgesi* DALL, 1908.
143. *nimbosa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 151. Hab. ? Coll. Cuming. Size: 25 lin. (= 56.3 mm). Lectotype: 58.8 mm; syntypes: 64.9 mm, and 58.7 mm (worn and faded), and 52.6 mm. = *Hastula hectica* (LINNAEUS, 1758).
144. *nitida*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 152. Hab. Marquesas. Coll. Belcher. Size: 10 lin. (= 22½ mm). Holotype no. 1844.6.7.85: 20.5 mm.
145. *nodularis*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 295. Hab. Les Îles Sandwich. Coll. Cuming & Deshayes ("ex Pease" on label). Size: 35×6 mm. Holotype: 34×6 mm; syntypes: 37.1 mm, and 33.0 mm.
146. *obesa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 158. Hab. ? Coll. Cuming; unique! Size: 6 lin. (= 13.5 mm). Holotype no. 1968250: 13.6 mm. The labrum of the aperture is lirate in the type.
147. *pallida*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 87, plt. 4, fig. 3. Hab. Les Îles Marquises. Coll. Cuming. Size: 72×11 mm. Holotype: 71.8 mm; syntypes: 59.2 mm (erroneously marked with x inside aperture), and 51.9 mm. The holotype is the same species as *T. punctatostriata* GRAY, 1834; the two smaller syntypes are *T. cingulifera* LAMARCK, 1822.
148. *parva*, *Terebra* (*Leiotoma*) BAIRD in BRENCHELEY, 1873, *Cruise H. M. S. Curaçao*, p. 435, plt. 37, figs. 5, 6. Hab. New Caledonia. Size: 8-11 lin. × 2 lin. (= 18-24.8 mm × 4.5 mm). Lectotype no. 56: 22.8 mm (marked with an x on the tablet near the apex of the shell); paralectotype no. 65: 18.4 mm.
149. *paucistriata*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 269. Hab. Ovalau, Fiji Islands (J. MacGillivray, H. M. S. *Rattlesnake*). Size: 19×4 mm. Holotype no. 1856.11.3.17: 18.6 mm.
150. *peasii*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 302. Hab. Les Îles Sandwich ("ex Pease" on label). Size: 45×9 mm. Holotype: 45.6 mm.
151. *pellyi*, *Terebra* – E. A. SMITH, 1877, A. M. N. H., 19: 226. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: 13×3 mm. Holotype no. 73.7.5.1: 12.4 mm (spot of red wax on whorl above aperture and marked with x under specimen on tablet). There are additionally 7 syntypes in the type collection, all smaller than the holotype.
152. *penicillata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 157. Hab. Seychelles. Coll. Belcher & Cuming ("ex Rousseau" on label). Size: 17 lin. (= 38.3 mm). Holotype no. 1968244: 40.0 mm; syntypes: 34.4 mm, and 26.4 mm.
153. *persica*, *Terebra* – E. A. SMITH, 1877, A. M. N. H., 19: 225. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: 12×3 mm. Holotype no. 73.7.5.4: 11.4 mm; syntypes: 10.0 mm, 9.0 mm, and 8.1 mm.
154. *petiveriana*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 85, plt. 5, fig. 10. Hab. Panama. Coll. Cuming. Size: 42×10 mm. Holotype: 43.0 mm (marked with x inside aperture); syntype: 40.9 mm. = *T. radula* HINDS, 1844.
155. *polygonia*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 289. Hab. Îles Marquises? Size: 8×2½ mm. Lectotype: 9.3 mm. Two specimens have been previously attached to the tablet on either side of the lectotype, but these are missing now. = *Hastula albula* (MENKE, 1843).
156. *polygonia*, *Terebra* – REEVE, 1860, *Conch. Icon.*, plt. 27, spec. 154. Hab. ? Coll. Taylor. Size of figure: 10.6 mm. Holotype no. 74.12.11.302: 10.7 mm.
157. *polygyrata*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 301. Hab. Les Îles Philippines. Coll. Cuming. Size: 13×3 mm. Holotype: 12.6 mm.
158. *praelonga*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 315. Hab. Port Curtis. Coll. Cuming. Size: 93×9 mm. Holotype: 92.4 mm; syntype: 102.6 mm (erroneously selected as the "type" in the collection). = *T. triseriata* GRAY, 1834.
159. *pretiosa*, *Terebra* – REEVE, 1842, P. Z. S. L., p. 200 & 1842, *Conch. Syst.*, 2: plt. 274, fig. 2. Hab. ? ("China" on label). Coll. Stainforth. Size: 59/16 × ½ poll. (= 141.3×17.4 mm). Obtained by Cuming; unique! Holotype: 140 mm; another specimen, 136.6 mm long, is present in the type collection which is not a type, as the specimen was said to be unique at the time of description.
160. *pulchella*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 94, plt. 5, fig. 4 (non *Epitonium pulchellum* NOODT, 1819). Hab. les mers de la Chine. Coll. Cuming. Size: 40×8 mm. Holotype: 39.2 mm; syntype: 41.2 mm (erroneously marked x inside aperture).
161. *pulchra*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 151. Hab. Marquesas. Coll. Belcher. Size: 11 lin. (= 24.7 mm). Holotype: 24.7 mm. = *T. cerithina* LAMARCK, 1822 (juvenile specimen).
162. *punctatostriata*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 61. Hab. ? Coll. J. E. Gray. Size: 2¾" (= 69.9 mm). Holotype no. 74.11.10.1: 70.2 mm. This species is not conspecific with *T. cingulifera* LAMARCK, 1822, but is an earlier name for *T. pallida* DESHAYES, 1857.
163. *pura*, *Terebra* – DESHAYES, 1857, J. C. P. 6: 82, plt. 5, fig. 8. Hab. Zanzibar. Coll. Cuming. Size: Not given in 1857; (69×11 mm in 1859). Holotype: 64.7 mm (marked x inside aperture, also on whorl

- above aperture and near apex of the shell on the tablet). Syntypes: 51.5 mm, and 45.8 mm.
164. *pustulosa*, *Terebra* – E. A. SMITH, 1879, P. Z. S. L., p. 186 (nom. nov. pro *T. granulosa* E. A. SMITH, 1873 – non LAMARCK, 1822). For types see under *T. granulosa* E. A. SMITH.
165. *radula*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155 (non GRAVENHORST, 1807). Hab. Puerto Potrero, west coast of America. Coll. Cuming. Size: 19 lin. (= 42.7 mm). Holotype no. 1968236: 40.8 mm. = *T. panamensis* DALL, 1908 (*vide* CAMPBELL in KEEN, 1968), but *T. glauca* HINDS, 1844 is a small specimen of *T. radula*. *Terebra aspera* HINDS, 1844, is not *T. variegata* GRAY, 1834, as suggested by KEEN (1968), but is rather similar to *T. radula*; it differs in having 3 prominent spiral rows of coarse nodules on each whorl which do not have the tendency to form axial ribs; this, however, may be a variable factor.
166. *reevei*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 88, plt. 4, fig. 14. Hab. les îles Moluques. Coll. Cuming. Size: 52×11 mm (92×11 mm min 1859). Holotype: 50.9 mm; syntypes: 50.0 mm, and 45.5 mm. = *Duplicaria duplicata* (LINNAEUS, 1758).
167. *regina*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 67, plt. 3, fig. 7. Hab. le Sénégal (“Loanda” on label). Coll. Cuming. Size: 78×13 mm (89×13 mm in 1859). Holotype: 76.3 mm. = *T. corrugata*, LAMARCK, 1822.
168. *remanalva*, *Terebra* – MELVILL, 1910, A. M. N. H., 6: 12, plt. 2, fig. 21. Hab. Persian Gulf, Bundo Abbas and Bushire. Size: 31×7 mm. Holotype no. 1911.6.21.11: 33.8 mm (marked x inside aperture); paratype no. 1911.6.21.12: 22.9 mm. = a worn and faded *T. spectabilis* HINDS, 1844?
169. *robusta*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 149. Hab. Panama, Gulf of Nicoya, Gulf of Papagayo and San Blas, west coast of America. Coll. Belcher & Cuming. Size: 57 lin. (= 128.2 mm). Lectotype no. 1968171: 117.4 mm; syntypes: 136.7 mm, and 88.0 mm.
170. *roscata*, *Terebra* – ADAMS & REEVE, 1850, Voy. *Samarang*, Zool., p. 30, plt. 10, fig. 24. Hab. Sooloo Islands. Size of figure: 29.5 mm. Holotype: 29.2 mm; syntypes: 25.2 mm, 21.0 mm, and 6.8 mm (juvenile specimen).
171. *rudis*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 60. Hab. ? Coll. J. E. Gray. Size: 1½” (= 38.1 mm). Holotype no. 74.11.10.11: 36.8 mm. = *T. dislocata* SAY, 1822.
172. *rufocinerea*, *Terebra* (*Myurella*) – CARPENTER, 1857 – see KEEN, 1968, p. 428, plt. 58, fig. 73. = *T. variegata* GRAY, 1834.
173. *rufopunctata*, *Terebra* (*Hastula*) – E. A. SMITH, 1877, A. M. N. H., 19: 229. Hab. ? Coll. J. E. Gray. Size: 22×5 mm. Holotype no. 74.10.12.3: 21.6 mm (spot of red wax on whorl above aperture); syntypes: 19.9 mm, 19.6 mm, and 17.4 mm. = *Hastula trailii* (DESHAYES, 1859).
174. *sallacana*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 287. Hab. Mexico (Sallé). Coll. Cuming. Size: 24×5 mm. Holotype: 23½×5 mm; syntypes: 25.3 mm, and 23.2 mm. = *Hastula cinerea* (BORN, 1778).
175. *seratina*, *Terebra* – ADAMS & REEVE, 1850, Voy. *Samarang*, Zool., p. 30, plt. 10, fig. 20. Hab. Japan Island, Nagasaki Bay (“Isle of Luzon” on label). Size of figure: 45.0 mm. Holotype: 48.3 mm; syntypes: 55.8 mm, and 52.2 mm. The syntypes may possibly be later additions from the Philippines. = *T. anilis* (RÖDING, 1798).
176. *severa*, *Terebra* – MELVILL, 1897, P. M. S. L., 41 (7): 9, plt. 6, fig. 8. Hab. Mekran coast. Size: 14½×4 mm. Holotype no. 97.7.30.103: 14.8 mm.
177. *sicyodes*, *Terebra nitida* var. – MELVILL & SYKES, 1898, P. M. S. L., 3: 43, plt. 3, fig. 8. Hab. Andaman Islands. Size: 37×6 mm. Holotype no. 98.4.30.4: 35.0 mm. = *T. nitida* HINDS, 1844.
178. *similis*, *Terebra* – E. A. SMITH, 1873, A. M. N. H., 11: 265. Hab. ? (“Madras” on label). Coll. Cuming. Size: 22×6 mm. Questionable holotype: 27.4 mm. (= “*T. concolor* E. A. SMITH” on label).
179. *solida*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 78, plt. 3, fig. 11. Hab. le Japon. Coll. Cuming. Size: 30×8 mm. Holotype: 29.9 mm.
180. *sowerbyana*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 93, plt. 3, fig. 8. Hab. la mer de Gambie (“River Gambie, Mr. Deal” on label). Coll. Cuming. Size: Not given in 1857, 56×12 mm in 1859. Holotype: 56.3 mm.
181. *specillata*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 155. Hab. San Blas (“San Blas, Mexico” on label). Coll. Belcher. Size: 20 lin. (= 45.0 mm). The only specimen present in the type collection is a Cuming specimen no. 1844.6.7.84: 39.3 mm, and is most probably a paratype.
182. *speciosa*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 279 (non BEAN in THORPE, 1844). Hab. ? (“West Africa” on label). Coll. Cuming & Deshayes. Size: 39×7 mm. Holotype: 39.8×7.6 mm. = *T. senegalensis* LAMARCK, 1822.
183. *spectabilis*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 150. Hab. Guinea and Sumatra. Coll. Cuming (“ex E. Layard” on label). Size: 13½ lin. (= 30.4 mm).

- Questionable syntypes: 49.7 mm, 38.0 mm, and 35.8 mm. ("= *T. gracilis* GRAY, 1834" on label).
184. *straminea*, *Terebra* - GRAY, 1834, P. Z. S. L., p. 62. Hab. ? Coll. J. E. Gray. Size: $2\frac{1}{2}$ " (= 63.5 mm). Holotype: 63.0 mm (marked x inside aperture). There are another 2 larger specimens in the type collection ex coll. Cuming from the Philippine Islands, which are not type material. = worn and faded *T. anilis* (RÖDING, 1798).
 185. *striata*, *Terebra* - GRAY, 1834, P. Z. S. L., p. 60 (non BASTEROT, 1825; nec QUOY & GAIMARD, 1833). Hab. ? Coll. J. E. Gray. Size: $1\frac{1}{2}$ " (= 38.1 mm). Holotype no. 74.10.11.3: 35.0 mm (juvenile specimen). = *T. babylonia* LAMARCK, 1822.
 186. *stylata*, *Terebra* - HINDS, 1844, P. Z. S. L., p. 152. Hab. Japan, Philippine Islands ("Cagayan, Island of Mindanao" on label). Coll. Cuming. Size: 21 lin. (= 47.3 mm). Holotype no. 1968230: 48.8 mm; syntypes: 49.3 mm, and 38.0 mm.
 187. *subnodosa*, *Terebra* (*Myurella*) - CARPENTER, 1857 - see KEEN, 1968, p. 428, plt. 58, fig. 72. = *T. intertincta* HINDS, 1844.
 188. *subtextilis*, *Terebra* - E. A. SMITH, 1879, P. Z. S. L., p. 185, plt. 19, fig. 3. Hab. Station 21; Japan. Coll. J. G. Jeffreys. Size: 37×6 mm. Holotype no. 78.10.16.28: 35.0 mm. = *T. textilis* HINDS, 1844.
 189. *succinea*, *Terebra* - HINDS, 1844, P. Z. S. L., p. 149. Hab. ? Coll. Cuming. Size: 54 lin. (= 121.5 mm). Probable holotype no. 1968172: 113.5 mm (marked x inside aperture); syntypes: 100.6 mm, and 78.8 mm (juvenile specimen).
 190. *sumatrana*, *Terebra strigilata* - THIELE, 1925, Wiss. Erg. Deut. Tief. Exp. Valdivia, 17: 344, plt. 29, fig. 20. Hab. Sumatra. Ex coll. Berlin Museum. Paratypes no. 1948.12.10.3-4: 18.7 mm, and 12.8 mm. = *Hastula strigilata* (LINNAEUS, 1758).
 191. *suspensa*, *Terebra* - E. A. SMITH, 1904, Journ. Malac. 11: 30, plt. 2, fig. 12. Hab. Port Elizabeth ("Pt. Alfred, Cape Colony; ex Turton" on label). Size: 20×4.5 mm. Holotype no. 90.3.12.19.858: 19.8 mm. Syntypes no. 90.3.12.19.859-862: 18.0 mm, 17.5 mm, 16.3 mm, and 16.1 mm.
 192. *swainsoni*, *Terebra* - DESHAYES, 1859, P. Z. S. L., p. 299. Hab. Les Isles Sandwich. Coll. Cuming ("ex Pease" on label). Size: 30×5 mm. Holotype: 30.0×6.0 mm; syntypes: 30.2 mm, and 26.5 mm.
 193. *tanilla*, *Myurella* - E. A. SMITH, 1873, A. M. N. H., 11: 270. Hab. Japan (A. Adams). Coll. Cuming. Size: $6\frac{1}{2} \times 2\frac{1}{2}$ mm. Holotype no. 73.7.5.2: 7.5 mm (marked with an x above the apex of the shell on the tablet). There are another 3 specimens in the type collection, ex coll. R. MacAndrew, mounted on the same tablet on the extreme right, but these are not type material.
 194. *taylori*, *Terebra* - REEVE, 1860, Conch. Icon., plt. 23, spec. 124. Hab. Torres Strait, Australia. Coll. Taylor. Size of figure: 27.2 mm (? enlarged). Probable holotype no. 74.12.11.300: 19.3 mm.
 195. *tenera*, *Terebra* - HINDS, 1844, P. Z. S. L., p. 158. Hab. Straits of Malacca; Ceylon. Coll. Belcher. Size: 4 lin. (= 9.0 mm). Three syntypes present instead of two, no. 44.6.7.86-67: 6.2 mm, 5.9 mm, and 5.8 mm; one of the three specimens is not a type.
 196. *textilis*, *Terebra* - HINDS, 1844, P. Z. S. L., p. 156. Hab. Sorsogon, Bay of Manila, Philippines; Straits of Macassar. Coll. Cuming & Belcher. Size: $11\frac{1}{2}$ lin. (= 25.9 mm). Holotype: 25.7 mm (spot of red wax on whorl above aperture and x marked inside aperture); syntypes: 22.4 mm, and 22.3 mm. Another 15.2 mm specimen ex coll. Belcher is a different species.
 197. *thyraea*, *Terebra* (*Euryta*) - MELVILL, 1897, M. P. L. P. S., 41 (7): 10, plt. 6, fig. 13. Hab. Karachi and Mekran coasts. Size: 12×4 mm. Holotype no. 97.7.30.89: 11.9 mm.
 198. *tiarella*, *Terebra* - DESHAYES, 1857, J. C. P., 6: 91, plt. 5, fig. 7. Hab. Natal. Coll. Cuming. Size: 32×8 mm. Holotype: 31.6 mm; syntype: 31.1 mm. The locality indication is erroneous, as the types appear to be conspecific with *T. fitchi* BERRY, 1958.
 199. *torquata*, *Terebra* - ADAMS & REEVE, 1850, Voy. Samarang, Zool., p. 30, plt. 10, fig. 13. Hab. China Sea ("Nagasaki Bay, Japan" on label). Coll. Cuming. Size of figure: 45.0 mm. Holotype: 45.5 mm; syntype: 52.1 mm. There are another 2 specimens in the type collection, 34.1 mm, and 22.9 mm in length, ex coll. J. G. Jeffreys, which are probably later additions; the locality of "Japan" on the label probably applies to the Jeffreys specimens.
 200. *traillii*, *Terebra* - DESHAYES, 1859, P. Z. S. L., p. 285. Hab. Vasingapatam, Océan Indien ("Madras Presidency, India" on label). Coll. Cuming. Size: $23 \times 4\frac{1}{2}$ mm. Lectotype: 23.8×4.6 mm; syntypes: 24.9 mm, 24.2 mm, and 22.4 mm.
 201. *trincta*, *Terebra* - E. A. SMITH, 1877, A. M. N. H., 19: 225. Hab. Persian Gulf (Colonel Pelly). Coll. R. MacAndrew. Size: $11 \times 2\frac{1}{2}$ mm. Holotype no. 73.7.5.6: 10.9 mm; syntype: 10.8 mm.
 202. *triseriata*, *Terebra* - GRAY, 1834, P. Z. S. L., p. 62. Hab. ? Size: $1\frac{1}{4}$ " (= 44.5 mm). Holotype no. 74.9.9.1: 46.7 mm.
 203. *trismacaria*, *Terebra* - MELVILL, 1917, J. C. L., 15: 188, text fig. Hab. Mekran coast, probably off Charbar. Size: 18×4 mm. Holotype no. 1925.3.12.14:

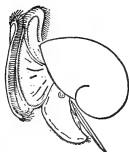
- 17.0 mm. = *T. polygyrata* DESHAYES, 1859.
204. *tristis*, *Terebra* – DESHAYES, 1859, P. Z. S. L., p. 306. Hab. les mers du Japon (= error! the species occurs in New Zealand waters). Coll. Cuming. Size: 19×9 mm. Holotype: 17.7 mm; another specimen, 14.8 mm in length, is a J. E. Gray specimen. Deshayes' stated width of 9 mm is obviously an error for 6 mm.
205. *trochlea*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 89, plt. 5, fig. 6. Hab. Zanzibar. Coll. Cuming. Size: 65×13 mm (69×13 mm in 1859). Holotype: 65.3 mm (marked x inside aperture); syntype: 50.5 mm (juvenile specimen).
206. *tuberculosa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 154. Hab. Panama, Gulf of Papagayo and San Blas. Coll. Belcher. Size: 24 lin. (= 54.0 mm). Holotype no. 1844.6.7.82: 55.7 mm (marked x inside aperture); syntypes (ex coll. Cuming, Panama): 46.4 mm, and 42.6 mm. The holotype of *T. tuberculosa* is not like the shell figured for the species by CAMPBELL (1964) on plt. 17, fig. 7, but rather similar to *T. cracilentia* LI, 1930, as figured by the same author on plt. 17, fig. 9. The penultimate whorl has 4 spiral rows of small nodules and the body whorl 7 rows up to the peripheral ridge.
207. *turrita*, *Myurella* – E. A. SMITH, 1873, A. M. N. H., 11: 266. Hab. Torres Strait. Coll. Cuming. Size: $26 \times 4\frac{1}{2}$ mm. Holotype: 23.0 mm. = *T. exigua* DESHAYES, 1859.
208. *undulata*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 60. Hab. ? Size: $1\frac{1}{2}$ " (= 38.1 mm). Coll. J. E. Gray. Lectotype no. 74.11.10.5: 33.6 mm; syntypes: 33.3 mm, and 32.7 mm.
209. *ustulata*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 97, plt. 3, fig. 12. Hab. la Terre de Van Diemen. Coll. Cuming. Size: 35×10 mm. Holotype: 35.0×10.7 mm (marked x inside aperture); syntypes: 36.9 mm, and 31.3 mm. There are another 3 specimens in the type collection which are not type material but have been purchased at a later date.
210. *varicosa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 152 (non *Buccinum varicosum* Gmelin, 1791; nec *Terebra varicosa* Bosc, 1801). Hab. Gulf of Papagayo, west coast of Central America. Coll. Belcher. Size: 11 lin. (= 24.8 mm). Holotype no. 1844.6.7.88: 25.0 mm; questionable Cuming syntype: 19.8 mm. It is suspected that sometime during labelling the smaller Cuming specimen has been interchanged with the larger Belcher specimen; from the dimensions supplied by HINDS, it is evident that the larger holotype originated from the Belcher collection. = *T. brunneocincta* PILSBRY & LOWE, 1932 (fide CAMPBELL in KEEN, 1968), but *T. larvaeformis* HINDS, 1844 is the same species.
211. *variata*, *Terebra* – GRAY, 1834, P. Z. S. L., p. 61. Hab. ? Coll. J. E. Gray. Size: $2\frac{1}{2}$ " (= 63.5 mm). Holotype: 61.4 mm (marked x inside aperture). There are 2 other specimens in the type collection ("Guaymas, Gulf of California, ex Mr. Babb?" on label) 78.0 mm and 61.7 mm in length, which are later additions and not type material.
212. *venilia*, *Terebra* – TENISON-WOODS, 1880, Proc. Linn. Soc. N. S. W., 4: 23, plt. 4, figs. 2, 2a. Hab. Sow and Pigs reef, Port Jackson. Size: $42 \times 7\frac{1}{2}$ mm. Holotype no. 96.11.30.28: 41.1 mm.
213. *venosa*, *Terebra* – HINDS, 1844, P. Z. S. L., p. 157. Hab. ? Coll. Cuming. Size: 16 lin. (= 36.0 mm). Holotype no. 1968245: 35.0 mm; syntypes: 34.9 mm and 27.0 mm. = *Hastula penicillata* (HINDS, 1844).
214. *virginea*, *Terebra* – DESHAYES, 1857, J. C. P., 6: 83, plt. 4, fig. 12. Hab. Zanzibar. Coll. Cuming. Size: 52×11 mm. Holotype: 52.3 mm. = worn and faded *T. consors* HINDS, 1844.
215. *walkeri*, *Terebra* – E. A. SMITH, 1899, P. M. S. L., 3: 312, fig. 1. Hab. Holothuria Banks, North-West Australia; J. J. Walker. Size: 26×6 mm. Holotype no. 91.11.21.326: 26.2 mm (juvenile specimen).
216. *wilkinsi*, *Strioterebrum* (*Partecosta*) – DANCE & EAMES, 1966, P. M. S. L., 37: 42, plt. 3, fig. 4 & plt. 5, fig. 5. Hab. Fao, Persian Gulf. Coll. W. D. Cuming. Size: 9.2×2.8 mm. Holotype no. 1893.12.15.74: 9.2 mm; plus 6 paratypes nos. 1893.12.15.75-80. = *Terebra fuscobasis* E. A. SMITH, 1877.

TOMLIN (1944) did not locate the type specimens of the following species: *Terebra archimedis* DESHAYES, *T. buccinum* DESHAYES and *T. lactea* DESHAYES; these types were in the type collection when I examined them. However, I did not find the type of *T. histrio* DESHAYES, 1857, which TOMLIN (*loc. cit.*) reported as being in Cuming's collection.

For 14 species TOMLIN reported a single type in each case but I found 2 or more syntypes present in the type collection. It is obvious that in the short span of time since TOMLIN reported on DESHAYES' *Terebra* types, the type collection has undergone changes, and more types are now present in the type collection than there were in 1944. It is probable that additional types have been isolated and removed from the general collection. Apart from *bona fide* holotypes and lectotypes, remaining syntypes are E. A. Smith's, Melville, and Melville and Sykes material excluded, rather questionable paratype material.

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The Ecology of *Macoma inconspicua* (BRODERIP & SOWERBY, 1829) in Central San Francisco Bay.

Part I. The Vertical Distribution of the *Macoma* Community

BY

MARILYN T. VASSALLO

Department of Biological Sciences
California State College at Hayward, Hayward, California 94542¹

(Plate 44; 6 Text figures; 2 Tables)

INTRODUCTION

THE PRESENT STUDY of the distribution of *Macoma inconspicua* (BRODERIP & SOWERBY, 1829) (= *Macoma balthica* LINNAEUS, 1758) community of central San Francisco Bay is of significance as no systematic subtidal or intertidal studies have been made in the expanse of shallow water (less than 5 m in depth) covering 48% of the central bay.

The purpose of this research was fourfold: (1) to delineate the vertical distribution of the fauna, (2) to describe the physical structure of the community within the mud, (3) to observe the interactions among the invertebrate fauna, and (4) to compare this community to parallel communities investigated by other authors. The second aspect of the study will be discussed in a later paper.

In this paper the name *Macoma inconspicua* is treated synonymously with *M. balthica* as in previous studies on this species in the San Francisco Bay region.

LOCATION OF THE STUDY

San Francisco Bay is located in the central portion of California. For purpose of discussion, it is convenient to divide San Francisco Bay into 3 sections: northern, central and southern. Because the United States Coast and

Geodetic Survey does not recognize these divisions, previous authors have used conflicting boundaries.

Although the U. S. Coast and Geodetic Survey has not defined north, central, and south San Francisco Bay as such, its charting system divides the northern region from the central portion in maps 5531 and 5532. Central San Francisco Bay is here defined as bounded on the north by a line extending from Hunters Point to Bay Farm Island and on the south by the San Mateo Bridge. These boundaries were used by GRAM (1966) in his comprehensive study of the marine geology of central San Francisco Bay.

Benthic samples analyzed in this study were taken from an intertidal mud flat bordering the ponds of the Oliver Brothers' Salt Company on the east side of central San Francisco Bay one half mile north of the San Mateo Bridge (Text figure 1).

PREVIOUS ECOLOGICAL STUDIES

Previous ecological studies have, for the most part, been restricted to subtidal work by investigators who operated a dredge from a large boat or ship. The U. S. S. "Albatross", commissioned by the U. S. Bureau of Fisheries to make a biological survey, cruised San Francisco Bay from January 1912 to April 1913 (PACKARD, 1918a). A report of the physical conditions from Suisun Bay to San Mateo Point based on data taken during this cruise was made by SUMNER *et al.* in 1914. This work was preceded by the limited geological investigations made

¹ Present address: Department of Biological Sciences, University of Victoria, Victoria, B. C., Canada

from the Russian ship "*Rurik*" in 1816 (in GRAM, 1966) and the biological investigations of H. M. S. "*Blossom*" in 1826 (ROSEWATER, 1968).

The report by SUMNER *et al.* (1914) was the basis of ecological studies made on the molluscan fauna by E. L. PACKARD. His first report was a qualitative study based on the fauna obtained from "several common types of dredges" (1918a). The second study was quantitative based on material taken with an orange peel dredge, the first time such a dredge was used in biological studies (PACKARD, 1918b).

Another early investigation of the physical factors of the bay was that of MILLER *et al.* in 1928.

Extensive work in the northern part of the bay has been carried out by FILICE (1954a, 1954b, 1958) and M. L. JONES (1961). In his work on the distribution of invertebrates in the northern bay FILICE used both Ekman and Petersen dredges. JONES collected his samples off Point Richmond with a core sampler.

An investigation of water sediment quality and pollution characteristics of the bay was made by McCARTY (1962). This study was followed by a faunal study in which samples were taken with an orange peel dredge in the north and central bay (STORRS *et al.*, 1965). Most recently, samples from 6 stations in the north and central bay were taken, again with an orange peel dredge, by APLIN (1967).

PHYSICAL CHARACTERISTICS OF THE ENVIRONMENT

TIDES:

On the Pacific coast two high tides of unequal magnitude and two low tides also of different heights occur during each lunar day. San Francisco Bay communicates to the ocean through the narrow Golden Gate. The narrow opening creates a lag in the time of low and high tides between the entrance to the bay and the southern reaches of the bay. At the San Mateo Bridge low tide is 1 hour 14 minutes later and 0.1 ft higher than at San Francisco (Fort Point). MILLER (1928) and GRAM (1966) have emphasized that the time and height of the tide is influenced by the prevailing winds. The wind is generally from the northwest and 46% of the time is between 4 and 10 knots (CONOMOS, 1963).

WAVES:

Due to the shallow character of the central bay, the prevailing winds produce an important amount of wave activity. GRAM (1966) calculates that in east central San

Francisco Bay "the water depths are such that waves two feet or less in height would readily disturb the bottom material, thereby allowing the materials once deposited to again become suspended and probably transported."

The term wave front seems more appropriate than surf as a description of the advancing edge of the tide on a mud flat. The wave front of the incoming and outgoing tides suspends and carries sediment with it.

CURRENTS AND SEDIMENTS:

Ripples in a substrate indicate the presence of a current. On the Oliver Brothers' mud flat ripples are formed on the mud closest to shore and tend to diminish towards the lower part of the mud flat (Plate 44, Figures 1 to 3).

The upper zone is most frequently subjected to sediment suspension by the wave front. SANDERS (1956) and KIRCHING *et al.* (1952) note that suspended sediments will tend to be deposited where the current which carries them decreases in speed. The largest particles are first to settle out and then, as the current decreases, smaller and smaller particles will settle.

On the present study site the combination of current (as reflected by ripples) and wave action produces a gradient in which coarse sediments are left in the upper part of the mud flat and the finest settle in the lower part of the flat.

METHODS AND MATERIALS

LINE TRANSECTS:

The relationship between tide level and distribution was determined by taking core samples along 3 line transects. Because the slope of the mud was very slight (especially below the 1.5 ft tide level), a tidal difference of one tenth of a foot would bare 30 m to 70 m of mud. Exposure in this broad band of mud was the same, so samples were taken at 36.6 m intervals.

The first line of 22 samples was taken from May 10 to June 3, 1967. This line was perpendicular to the shoreline and extended up into a small creek which drains the surrounding marshland.

A line parallel to the first and 180 m south was sampled the following month from June 10 to June 22. The backshore of this area consisted of a rock and concrete levee. Twenty-one samples were taken.

From July 1 to July 12 a third set of 20 samples was taken along a line north of the first line lying at a 30° angle to it. The backshore consisted of marshland (Text figure 1).

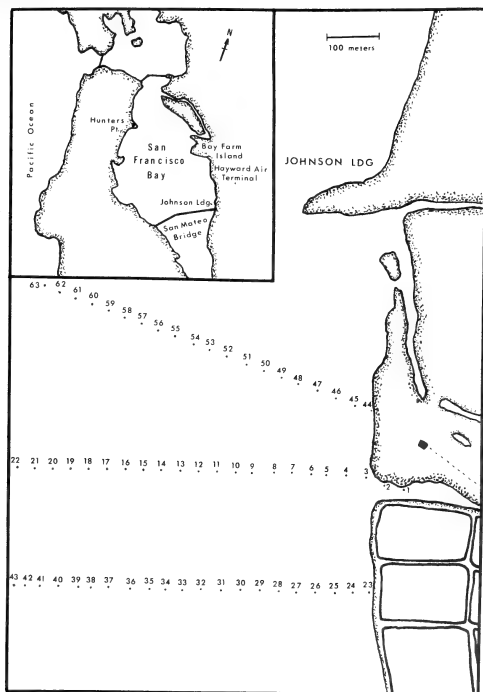


Figure 1

Number and location of samples taken on the Oliver Brothers' mud flat. The scale on the figure refers only to the east-west dimension of the tide flat which is somewhat foreshortened in the north-south direction. The map is based on an aerial photograph taken from an oblique (south to north) angle.

CONSTRUCTION OF THE SAMPLERS:

Two parameters were utilized to measure the fauna of the mud flat. The organisms in the mud were measured as numbers of individuals per core (in cubic centimeters). Those living on the mud surface were measured as numbers of individuals per quadrat (in square centimeters).

The core sampler consisted of an aluminum casing which fit snugly over a half-gallon milk carton with its base removed. The cross section of a half-gallon milk carton is 9.7 cm by 9.7 cm; the area 94.09 cm². This is less than 6% short of a sampling area of 0.01 m².

To obtain a sample of mud the casing with the carton in it was pushed into the mud and brought up with a shovel. The carton was prevented from collapsing by applying strips of masking tape to the inside of the carton which were then extended through the bottom of the carton to the outside of the casing.

Previous authors have sampled to varying depths for *Macoma inconspicua*. FRASER (1932) went to a depth of 7.5 cm. No reason was given for this limitation, nor did REES (1940) explain why he sampled to a depth of 18 cm. BEANLAND (1940) took only the top 2.5 cm because: "Previous work in the area seemed to indicate that the surface inch contained a representative fauna." BRADY (1943) sampled to a depth of 25 cm since the organisms did not penetrate to a greater depth.

Preliminary work on the Oliver Brothers' mud flat revealed a dense layer of clay about 20 cm beneath the surface. No animals penetrated into the clay; therefore, a sampling depth of 21 cm was chosen.

Counting the numerous thread-like polychaetes was facilitated by subsampling. At one corner of each sample a 3 cm by 3 cm by 21 cm section was marked off. The subsample was sieved through a 0.297 mm mesh under running water. The upper 2 cm were also sieved through

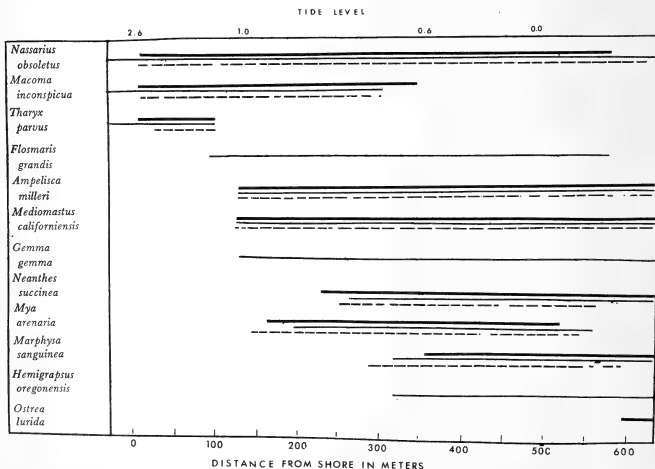


Figure 2

A comparison of the 3 transects. Heavy line, transect 1; light line, transect 2; dashed line, transect 3. Single light line indicates distribution of fauna not taken in the sampler in significant numbers.

a 0.297 mesh. A geologic sieve of 0.5 mm was used to sort the remainder of the sample.

SAMPLING FOR *Nassarius obsoletus* (SAY, 1822):

The mud snail *Nassarius obsoletus* (SAY, 1822) was extremely abundant on the mud surface. The milk carton sampler took an adequate volume of mud to obtain significant numbers of the infauna; however, even at optimum densities of *N. obsoletus* the surface area of 94 cm² could potentially take only 3 or 4 snails per sample. In addition, the mud snail's tendency to converge on a given area when a choice morsel of food was found also indicated a larger surface area should be taken.

An aluminum frame 50 cm by 50 cm by 5 cm was placed on the mud. The milk carton sample was taken in one corner and then the snails within the frame were picked up by hand.

RESULTS

DISTRIBUTION OF COMMON SPECIES:

The distribution according to tide level was the same for the 3 transects (Text figure 2). The difference in backshores did not appear to affect the faunal distribution except in the case of transect 1. The backshore of this transect consisted of a creek bed and the mud therefore extended beyond the marshland and the rock levee of the other transects.

The upper zone from the 2.5 ft tide level to 1.3 ft was characterized by *Nassarius obsoletus*, *Macoma inconspicua* and *Tharyx parvus* BERKELEY, 1929. Specimens of *Streblospio benedicti* WEBSTER, 1789 and *Flosmaris grandis* HAND & BUSHNELL, 1967 were occasionally observed in this region.

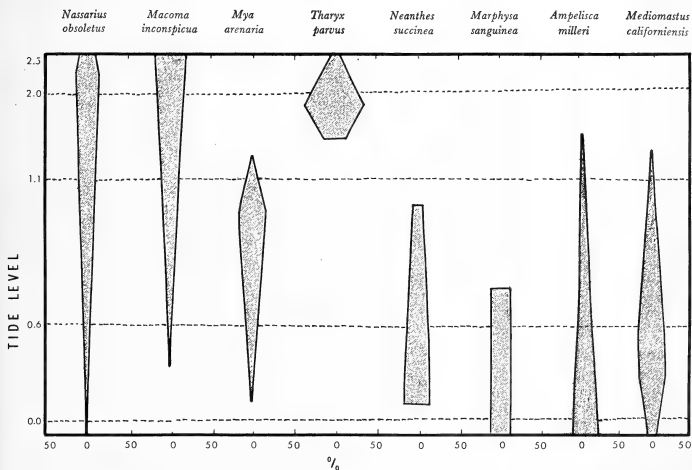


Figure 3

Per cent of each population at a given tide level.

From 1.2 ft to 0.9 ft several additional species appeared in the samples. This area appeared to be the upper limit for *Mediomastus californiensis* HARTMAN, 1944; *Neanthes succinea* (FREY & LEUCKART, 1847); *Marphysa sanguinea* (MONTAGU, 1804); *Mya arenaria* LINNAEUS, 1758; and *Ampelisca milleri* BARNARD, 1954. In addition, small numbers of *Gemma gemma* (TOTTEN, 1834); *Hemigrapsus oregonensis* (DANA, 1851) and a goby were recovered. This area corresponds to one of the critical tide levels described by DOTY (1946). At the levels of 3.5 (LLHW), 3.0 (HHLW) and 1.0 (LHLW) there is a sudden increase in duration of a single exposure.

At the end of the second transect *Ostrea lurida* CARPENTER, 1864 was abundant on the surface of the mud. Specimens of the slipper shell *Crepidula convexa* SAY, 1822 were found on the oysters. Specimens of the anemone *Diadumene leucolela* (VERRILL, 1866), two possessing catch tentacles (VASSALLO, in press), were also found on the oysters.

Text figure 3 represents the per cent of individuals in 8 common populations found at a given tide level.

Nassarius obsoletus

A total of 348 mud snails were taken in 43 quarter meter square samples. The maximum number taken in a single sample was 36. There was a gradual decrease in the numbers from the optimum region at 2.4 ft where 13% of the population was found.

Macoma inconspicua

Two hundred and fifty-six specimens of *Macoma inconspicua* were taken in 63 milk carton samples. The clam was most abundant at the 2.6 ft tide level. A maximum of 13 per core was found in the optimum region where 17.5% of the population occurred.

Mya arenaria

Seventy specimens of *Mya arenaria* were taken in the core sampler. The upper limit was 1.3 ft. The optimal region was 0.9 ft. No specimens were taken beyond the 0.1 ft level. No more than 3 specimens were recovered in a single core.

Neanthes succinea

A total of 11 specimens of this polychaete was taken with the core sampler. The maximum number per core was 2. *Neanthes succinea* was evenly distributed over its range. The upper limit found during this survey was 1.0 ft.

Marphysa sanguinea

Thirteen specimens of *Marphysa sanguinea* were obtained with the core sampler. No more than 1 specimen was found per core. The upper limit was 0.8 ft.

Mediomastus californiensis

Subsampling was utilized in the recovery of *Mediomastus californiensis* from the milk carton core. Sixty-three specimens of this polychaete were taken. The upper limit of the polychaete was 1.3 ft. There was an increase from 1 per subsample to 3 per subsample in the optimum area at 0.5 ft.

Tharyx parvus

The cirratulid polychaete was found from the shoreline out to a distance of 100 m. Limitation to the upper zone is apparently not the direct effect of exposure *per se* since JONES (1961) found it in high numbers at a station 3 ft below MLLW.

Ampelisca milleri

Counts of this amphipod were made along one transect because of the difficulty they presented to counting. Two hundred and fifty-five amphipods were taken in the subsamples from transect 2. The upper limit was about 1.2 ft where 3 amphipods per subsample were found. The numbers increased to the 0.7 ft level where a maximum of 29 per subsample were found. This is a conservative count. Sieving through a 0.297 mm mesh did allow some amphipods to pass through. When the mud was screened over trays, small amphipods passed through and within 2 days had built new tubes.

DISTRIBUTION OF THE DOMINANT SPECIES:

In a previous section on the sediments of the mud flat it was noted that ripples in the upper zone indicated a current was present along the shoreline. The current as well as the wave front of the incoming tide suspended sediment. Larger particles settled out first and lighter ones settled as the current decreased.

At a distance of 150 m from shore the ripples became less distinct until they were no longer present 300 m from shore. The area between 150 m and 300 m was intermediate in strength of current and in size and amount of particles deposited on the surface. This zone between the area experiencing strong currents and the lower zone where no current was apparent might be con-

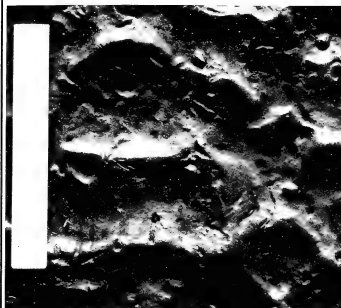


Figure 1

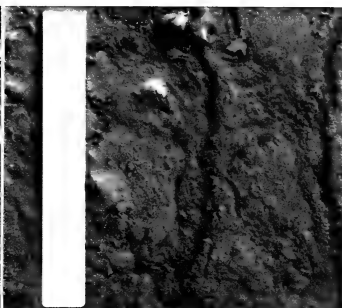


Figure 2



Figure 3

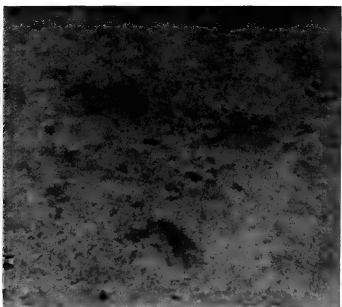


Figure 4

Figure 1: Detail of well defined ripples in the upper zone. Six inch rule for scale.

Figure 2: Detail of intermediate zone. Note faint ripples.

Figure 3: Lower zone of the mud flat. Ripples absent. Small projections from the mud are tubes of *Ampelisca milleri*. The snails covered with detritus and diatoms are *Nassarius obsoletus*.

Figure 4: Indentations characteristic of *Busycotypus canaliculatus* found in the lower zone of the mud flat.



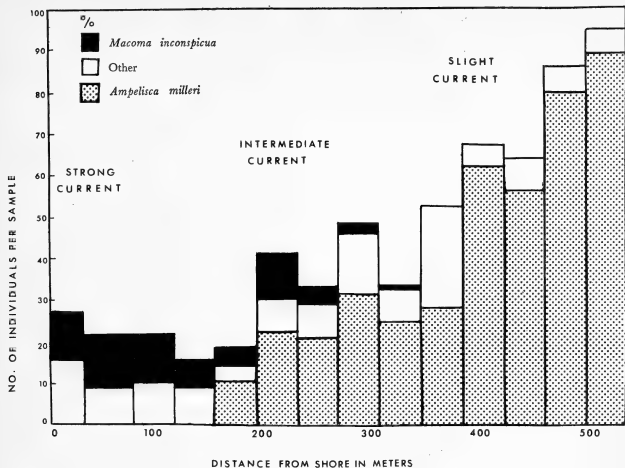


Figure 4

The dominant species of the community changes with distance from shore.

sidered an ecotone. The existence of an ecotone on an intertidal mud flat was suggested by DEXTER (1947).

In the upper zone of the mud flat from 2.6 ft to 1.3 ft *Macoma inconspicua* formed 55% of all the individuals in the community and the amphipod *Ampelisca milleri* represented 1% of the individuals. In the intermediate zone the per cent of *M. inconspicua* dropped to an average of 16% and the amphipod increased to 50%.

In the lowest zone from 0.8 ft to -0.1 ft *Ampelisca milleri* was the dominant species forming 90% of the community. The change of dominance is shown in Text figure 4. At the extreme ends of the figure two communities are evident.

DISCUSSION

THE *Macoma* COMMUNITY:

Macoma inconspicua occurs in subtidal (FORD, 1923; THORSON, 1957) as well as intertidal muds. BRADY (1943), SPOONER & MOORE (1940) and FRASER (1932) found no definite trend with respect to tide level. ALLEN (1954) reports *M. inconspicua* in mud as well as mud-sand. HOLME (1949) found it in soil ranging from moist sand to mud. Studies by BEANLAND (1940), REES (1940) and FRASER (1932) indicate that soil grade in itself does not appear to be the determining factor in the distribution of *M. inconspicua*.

BEANLAND suggests that the abundance of *Macoma inconspicua* in estuaries depends on two factors: (a) quality and quantity of available food supply correlated with type of soil; and (b) available feeding time correlated with distance below high tide mark.

YONGE (1949) found this species to be a detritus feeder. In the field as well as in the laboratory *Macoma incon-*

spicua was observed sweeping its siphon over the surface of the mud. In the course of the sweeping it would sometimes crook the end of the siphon into the mud as if to loosen the surface of the mud. The inhalant siphons extended several centimeters out of the mud. Although they were long enough to extend towards the water above them, the siphons remained sweeping at the detritus-water interface.

McNULTY *et al.* (1962) found detritus feeders most abundant in fine soils. On the Oliver Brothers' mud flat the greatest amount of detritus occurs in the lower zone. This area also has the greatest amount of feeding time, yet, contrary to BEANLAND's suggestion, *Macoma inconspicua* is most abundant in the upper zone where there is less detritus and less feeding time.

In summary, the literature indicates that there does not appear to be direct relationship between distribution and exposure or particle size. The present study does not support BEANLAND's suggestion that detritus and availability of feeding time are important factors.

THE *Ampelisca* COMMUNITY:

Ampelisca milleri is found subtidally to a record depth of 65 fathoms (BARNARD, 1967). In San Francisco Bay, JONES (1961) found it to be abundant at a station 3 ft below Mean Lower Low Water.

JONES (*op. cit.*) noted that the sediment was coarse at the station where *Ampelisca* was abundant and finer where it was present in smaller numbers. No other information on the ecology of *Ampelisca milleri* was found. ENEQUIST (1950) noted that the ampeliscid *Haploopsis* cannot build its tubes in pure clay or coarse sand. The tubes of *A. milleri* on the Oliver Brothers' mud flat were made of fine sediment. The need for tube construction could restrict the species to finer soils.

All of the ampeliscids studied by ENEQUIST were found to be detritus feeders. In the present study *Ampelisca* was observed in the laboratory to continuously sweep detritus with its long antennae and move particles toward its mouth - indicating this species may also be a detritus feeder.

In the intermediate and lower zones of the mud flat water does not drain completely from the mud flat. This residual water could serve to protect *Ampelisca* from desiccation. HART (1930) suggests that such a layer of water may protect *Corophium volutator* from desiccation. Like *Ampelisca milleri*, *C. volutator* feeds on detritus and lives at the mud surface in semi-permanent tubes (HART, *op. cit.*).

BEANLAND (1940) noted that when *Corophium* leaves its tube, it is at the mercy of the currents. *Ampelisca*

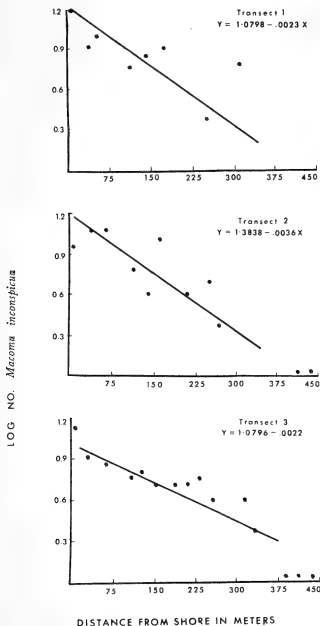


Figure 5

Regressions of the number of *Macoma* taken on the Oliver Brothers' mud flat

was observed caught in the movements of outgoing tides on the Oliver Brothers' mud flat. BEANLAND suggested that shelter may be an important factor affecting the distribution of *Corophium*. She noted that, where *Corophium* was found in previous studies, it occurred in sheltered areas where the amphipod was protected from currents which could sweep it away. GOODHART (1941) records that it is absent from steep banks where it might be washed away by the current.

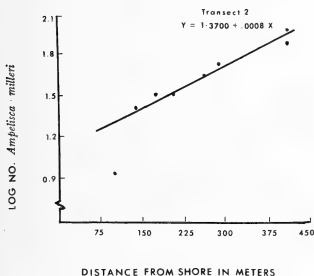


Figure 6

Regression of the number of *Ampelisca* taken on Oliver Brothers' mud flat

In the Dovey Estuary, BEANLAND found that as shelter decreases from shore to low water the numbers of *Corophium* decrease. On the Oliver Brothers' mud flat the presence of ripples in the upper tide level and their absence in the lower level indicates that "shelter" in the sense of less overturn of mud by the current increases with a decrease in tide level. The upper tide level is also less sheltered in the sense it is more frequently exposed to the sediment stirring influence of the incoming and outgoing tide.

In summary, the accumulation of detritus and the presence of shelter seem to be important in affording favorable conditions to the maintenance of the *Ampelisca* community in the lower zone of the mud flat.

It could be argued that the distribution (abundance in the upper flat) of *Macoma inconspicua* is due to physiological differences in the San Francisco Bay population.

However, north of this study area in upper San Francisco Bay, FILICE (1958) reports that *M. inconspicua* prefers the intertidal and upper 5 subtidal feet.

Predation by *Busycotypus canaliculatus* (LINNAEUS, 1758) may be a factor limiting *Macoma*. Large indentations made by the whelk have been found in the lower zone of the mud flat (Plate 44, Figure 4). No living specimens or shells have been dug from the mud or have been found on or near the Oliver Brothers' mud flat. However, hundreds of individuals of this species are found on the mud flats in west central bay and fishermen stranded by low tide about a mile from the east shore have observed the whelk on the mud surface.

The fact that *Busycotypus* has never been directly observed on the Oliver Brothers' mud flat and the presence of relatively few indentations (in contrast to abundant numbers occurring on exposed flats of west central bay) suggests that *Busycotypus* may not be a major limiting factor.

Both in San Francisco Bay and the Dovey Estuary (BEANLAND, 1940) numbers of detritus feeding amphipods populate the mud flats. In the Dovey Estuary the amphipod community dominates the upper tide levels (BEANLAND, *op. cit.*). As the level decreases, the numbers of amphipods decrease and the clam *Macoma inconspicua* appears and gradually replaces the amphipod as the dominant species. On the Oliver Brothers' mud flat it is *M. inconspicua* that dominates the upper tide level and is replaced by an amphipod community at the lower

Table 1

Faunal Change with Distance from High Tide Mark on the Oliver Brothers' Mud Flat

Sample No.	<i>Ampelisca milleri</i>	<i>Macoma inconspicua</i>
23	—	9
24	—	12
25	—	13
26	9	7
27	24	4
28	24	10
29	36	4
30	33	6
31	45	3
32	60	1
33	57	1
34	81	—
35	78	—
36	78	—
37	81	—
38	75	—
39	75	—

level. Tables 1 and 2 give the results of the present study and that of BEANLAND's study. In both areas the sample number represents increasing distance from shore. It should be noted that BEANLAND's sampling area was one meter square.

Table 2

Faunal Change with Distance from High Tide Mark,
BEANLAND, 1940

Sample No.	<i>Corophium volutator</i>	<i>Macoma inconspicua</i>
1	—	—
2	445	1
3	24	—
4	191	1
5	44	11
6	2	2
7	844	6
8	455	2
9	82	1
10	21*	2
11	20	1
12	29	—
13	1193*	16
14	1	11
15	5	7
16	24	15
17	2	19
18	1	8
19	—	401
20	—	195
21	—	369
22	—	416
23	—	657
24	—	58
25	—	4
26	—	—

* Probably a mixture of *Corophium volutator* and *C. arenarium*

The Tables and the regressions in Text figures 5 and 6 show an inverse relationship between the amphipod and *Macoma inconspicua*. The correlation itself does not necessarily imply a direct effect of one variable on another. However, the feeding habits of *M. inconspicua* and the amphipods suggest that this correlation may be significant.

That *Ampelisca* lies on its dorsum sweeping its antennae over the surface, has already been mentioned. If, indeed, this is an indication that it is a detritus feeder as were all of the ampeliscids studied by ENEQUIST (1950),

then the tremendous numbers of *A. milleri* (roughly 8000 individuals per m²) are significant competitors with *Macoma inconspicua* for this food.

In addition to competition for food, the sweeping habit could conceivably affect the spat fall. SEGERSTRALE (1957) reported that in an area of the Baltic, where the amphipod *Pontoporeia affinis* is abundant, the *Macoma inconspicua* population has failed over a number of years. He suggested that the amphipods may eat young *Macoma* as they sink to the bottom after the planktonic stage.

KANNEWORFF (1965) found that *Ampelisca macrocephala* feeds on detritus in the field. In his laboratory, however, the amphipod was observed to create currents in which *Mytilus* larvae, copepods and *Artemia salina* were carried to the gnathopods and then transferred to the mouth.

Pontoporeia and *Ampelisca macrocephala* are about 4 times larger than *A. milleri*. While *A. milleri* may not be large enough to prey on the spat, the sweeping motion of the antennae could prove a physical barrier to the spat.

At least 3 possibilities of competition between *Macoma* and *Ampelisca milleri* exist: (1) the use of detritus as food, (2) predation by the amphipod on the spat, and (3) physical interference with spat fall.

SUMMARY

1. The distribution of invertebrates on and in a mud flat of central San Francisco Bay was studied.
2. Near the 1.0 ft level, one of the critical tide levels cited by DOTY (1946), the number of animals in the mud flat increased.
3. Two communities were found on the mud flat. *Macoma inconspicua* was the most abundant organism in the upper zone. This community gradually gave way to one dominated by the amphipod *Ampelisca milleri*.
4. The distribution of *Macoma inconspicua* appears to be determined by currents which affect sediment settlement and by degree of shelter. Sediment and shelter favor the amphipod which competitively excludes *Macoma inconspicua*.

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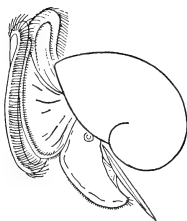
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Spawning of the American Oyster, *Crassostrea virginica*, at Extreme pH Levels

BY

ANTHONY CALABRESE

AND

HARRY C. DAVIS

Bureau of Commercial Fisheries, Biological Laboratory, Milford, Connecticut 06460

(Plate 45)

THE AMERICAN OYSTER, *Crassostrea virginica* (GMELIN, 1791), is the most important commercial mollusk of the Atlantic Coast and the Gulf of Mexico. Of the various interacting biological, physical, and chemical factors that affect oysters in these waters, pH has received less attention than any other major factor. PRYTHERCH (1928), who measured pH at several stations in Milford Harbor and the Milford area of Long Island Sound, found that it ranged from 7.2 to 8.4 during the day. He observed that oysters in Milford Harbor spawned at pH 7.8 and 8.2 and concluded that low pH inhibited oyster spawning and that oysters in Milford Harbor spawned at high tide because this was the only tidal stage at which the pH was between 7.8 and 8.2.

In laboratory experiments LOOSNOFF & TOMMERS (1947) determined that adult oysters kept in water adjusted to pH 4.25 remained open, on an average, 76% of the time, but pumped only 10% as much water as did control oysters kept in water of pH 7.75. Oysters kept at pH 6.75 and 7.00 initially pumped more vigorously than the controls, but the rate of pumping later decreased to less than that of the controls.

Although the pH of sea water usually ranges from 7.5 to 8.5, the pH in tidepools, bays, and estuaries may decrease to 7.0 or lower due to dilution and production of H_2S (SVERDRUP *et al.*, 1942). These inshore areas constitute a major portion of the habitat of oysters, and DAVIS & CALABRESE (1964) suggested that these regions may also be exceedingly important as nursery grounds for larval stages. Since oyster larvae must, at times, encounter a wide range in pH in their natural habitat, it is possible that success or failure of recruitment in some areas may be determined by variations in pH.

In previous studies CALABRESE & DAVIS (1966) found that normal development from the fertilized egg to the 48-hour, straight-hinge larval stage took place within the pH range from 6.75 to 8.75. In experiments with oyster larvae, which were terminated after 12 days at experimental pH levels, more than 68% of the larvae survived within the pH range from 6.25 to 8.75, and the lowest pH limit for survival was 6.00. The optimum pH for larval growth was from 8.25 to 8.50, although growth was good from 6.75 to 8.75. At pH 9.00 to 9.50 the percentage of eggs that developed normally, the percentage of larvae that survived, and the percentage increase in mean length decreased rapidly.

The present experiments were initiated to determine the minimum and maximum pH at which oysters will spawn and to determine the length of time that eggs and sperm remain viable at these extreme pH levels. The methods used at this laboratory for conditioning oysters and obtaining gametes have been described previously by LOOSNOFF & DAVIS (1963). In these experiments we placed oysters in normal laboratory sea water (pH approximately 7.8) and sea water adjusted to the desired pH level with either HCl or NaOH. We attempted to induce spawning by either of two methods: (1) by raising the temperature of the sea water to approximately 29° C and simultaneously adding to the sea water small quantities of sperm suspension made from gonadal material of ripe male oysters (combined thermal and chemical stimulation), and (2) by thermal stimulation only (Plate 45).

We concluded from these experiments that the minimum and maximum pH levels at which American oysters will spawn are 6.0 and 10.0, respectively. A summary of

the data collected at these pH levels is presented in Table 1.

Table 1

Spawning of American oysters at extreme pH levels as compared to spawning at normal pH

	Group 1		Group 2	
	pH 6.0	Normal pH (approx. 7.8)	pH 10.0	Normal pH (approx. 7.8)
Number of oysters used	155	114	118	100
Number spawned	23	58	28	46
Percentage spawned	14.8	50.9	23.7	46.0
Number of males spawned	21	38	19	27
Number of females spawned	2 ¹	20	9	19

¹ pH when spawning was observed was 6.4

As indicated in Table 1, the percentage of oysters that spawned at pH 6.0 and 10.0 was considerably lower than the percentage that spawned at normal pH of sea water. In all tests male oysters spawned more readily than females and at pH 6.0 it was most difficult to induce females to spawn.

To determine the viability of eggs and sperm from oysters spawned at pH 6.0 and 10.0 we induced spawning by thermal stimulation only. As male or female gametes were released, we attempted fertilization with male or female gametes released from spawners at normal pH. Eggs or sperm released at pH 6.0 or 10.0 were removed after 15, 30, 45, 60, 90, 120, 150, 180, 240, and 360 minutes of exposure to those pH levels and we tried fertilization with normal eggs or sperm to test viability. Although the data are insufficient to determine precisely how long eggs and sperm can tolerate these extreme pH levels, it is obvious that oyster eggs and sperm released at pH 6.0 and 10.0 lose their viability rapidly, and are no longer viable after 2 to 4 hours. GALTISOFF (1964) reported that fertilizability of oyster eggs kept under normal sea-water conditions decreased to about 20% in 10 hours, and that only a few eggs fertilized after 10 and 24 hours cleaved normally. He also stated that sperm, kept at room temperature in a dilute suspension, lost their fertilizing ability within 4 to 5 hours. In consideration of this finding we tried fertilization with 15- and 210-minute-old gametes from a male and female that spawned at normal pH. Development to the straight-hinge stage with the 15-minute-old gametes was 100%; with the 210-minute-old gametes development was only 77%. At this time

we also tried fertilization with 15- and 210-minute-old gametes from a male that spawned at pH 6.0 and the same female that spawned at normal pH. Development to the straight-hinge stage with the 15-minute-old gametes was 100%; with the 210-minute-old gametes development was only 48%. The lowered viability of eggs and sperm in these experiments was, therefore, due to a combination of pH and aging.

The spawning season of the American oyster in Long Island Sound extends from late June to early September (LOOSANOFF, 1965). During this time excessive changes of pH caused by siltation or pollution could cause a failure of recruitment of oysters into the population.

SUMMARY

The minimum and maximum pH levels at which the American oyster, *Crassostrea virginica*, will spawn are 6.0 and 10.0, respectively. Oyster eggs and sperm released at pH 6.0 and 10.0 lose their viability rapidly within 2 to 4 hours. Lowered viability was due, however, to a combination of pH and aging.

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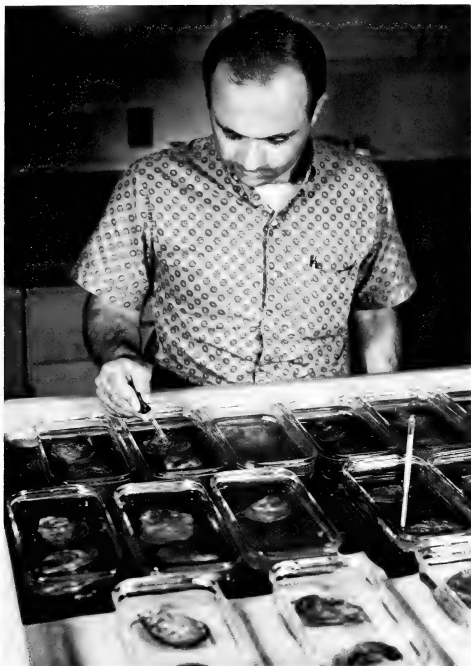


Figure 1

Inducing spawning of oysters by immersing dishes of sea water
containing oysters in warm water on spawning table and
adding sperm suspension



Invertebrates Taken in Six Year Trawl Study in Santa Monica Bay

BY

JOHN G. CARLISLE, Jr.

Marine Resources Operations, California Department of Fish and Game, California State Fisheries Laboratory
Terminal Island, California 90731

INTRODUCTION

IN 1958 THE BUREAU OF SANITATION, City of Los Angeles and the California Department of Fish and Game entered into an informal agreement as part of a surveillance program for Santa Monica Bay. The purpose of this study was to evaluate the effects on the marine environment, as measured by bottomfish catches, of waste discharges from the Hyperion Treatment Plant, the large scale sewage waste disposal plant for the City of Los Angeles. This plant discharged effluent varying from 261 to 283 million gallons of waste a day during the 6 years of the study. In addition, solids discharged into the ocean by the sludge line ranged from 130 to 156 tons per day. The effluent line is 5 miles long, the sludge line 7.

The biological work was done by Department of Fish and Game biologists; the City of Los Angeles provided the boat, equipment, and crew. In the past, all attempts to prove any long-term and subtle influence of major waste discharges on an open coastal biotope have failed (LUDWIG & ONODERA, 1964). A large amount of data was gathered during 6 years of trawling from 1958 through 1963. The analysis of the data pertaining to bottomfish populations is the subject of another report (CARLISLE, in press). The present report deals with the large quantity of invertebrates, primarily mollusks, taken incidental to the catch of bottomfish.

METHODS

Trawling was conducted from the *Prowler*, a 65-foot converted salmon troller used in the Santa Monica Bay monitoring program. Trawling equipment included a winch deriving its power from the main engine, and an A-frame on the fantail through which a single cable led over a block to the trawl net. A 25-foot cable bridle was

attached to a pair of otter boards fixed to short lines on the wings of the net. The boards were 12- by 18-inch steel-reinforced plywood weighted heavily along the bottom. The net was a 24-foot semi-balloon or tri-net with a body of 1½-inch mesh, number 18 twine. The liner of the bag was of ½-inch mesh synthetic material.

Thirty-nine regular stations in depths of 60 to 600 feet were sampled every 3 months. While difficulties in scheduling the boat and crew made it impossible to adhere to the quarterly program perfectly, it was followed as closely as possible.

Each trawl lasted 10 minutes, clocked from the time the net was on the bottom (and fishing) until the winch was started and net retrieving began. All fishes were returned to the California State Fisheries Laboratory for further study. Invertebrates were counted and returned to the water or saved for later identification. During the 6 years, 705 net hauls were made.

It was impossible to assess the catch of invertebrates in the same manner as the bottomfish because the net was designed to catch fishes and not invertebrates. However, the large incidental catch of invertebrates was of considerable interest since it provided information on population densities, distribution in depth and ecological associations. No attempt was made to evaluate the catches as proof of pollution or non-pollution of the area. Only live individuals were tallied; dead shells were abundant in many hauls but they were not noted since their distribution could have been influenced by currents or other factors.

ACKNOWLEDGMENTS

This research was begun and supervised for the first 5 years by John L. Baxter before I took over the project. The work accomplished and subsequent help on many

occasions are gratefully acknowledged. John E. Fitch was extremely helpful throughout the entire study.

Sincere thanks are due to many in a truly cooperative project, especially in carrying out the field work. The following, in particular, must be included: Gordon Chapman, William Craig, William Donnelly, Ronald Little, Dennis Peterson, and Donald Zumwalt. Norman J. Abramson also gave fully of his time with advice and help.

I would like to take this opportunity to thank the following personnel of The Hyperion Treatment Plant and the Los Angeles Bureau of Sanitation for their consideration through the years: Eugene Nelson, Charles Gunnerson, Homer Rheinschmidt, Charles Imel, John Stanton, and Joseph Arai.

Many thanks are also due those who helped in the task of invertebrate identification, particularly: S. Stillman Berry, James H. McLean, John Garth, Olga Hartman, and Fred Ziesenhenné.

Without all this help the project would have been truly impossible. One of the pleasures inherent in the completion of a research project is the opportunity to express gratitude to all those who made it possible.

LIST OF INVERTEBRATES TAKEN BY TRAWL INCIDENTAL TO FISH CATCHES, 1958 TO 1963

Frequency and Depth of Occurrence

PORIFERA

Occasional Depth range: 192 - 426 feet

COELENTERATA

<i>Stylatula</i> sp.	sea pens
Frequent	Depth range: 60 - 600 feet
<i>Rcnilla</i> sp.	sea pansy
Frequent	Depth range: 60 - 104 feet
Sea anemones	
Frequent	Depth range: 180 - 600 feet
Gorgonians	
Occasional	Depth range: 120 - 570 feet

ECHIUROIDEA

Listriolobus pelodes FISHER, 1946
Occasional Depth range: 108 - 354 feet

SIPUNCULOIDEA

Occasional Depth range: 174 - 192 feet

ANNELIDA

Polychaeta
Aphrodita refulgida MOORE, 1910 sea mouse
Frequent Depth range: 60 - 600 feet
Phyllochaetopterus sp. sea mouse
Occasional Depth range: 60 - 300 feet
Hyalinoccia juvenalis MOORE, 1911
Occasional Depth range: 186 - 300 feet
Pectinaria californiensis HARTMAN, 1941
Frequent, extremely large numbers at times
Depth range: 360 - 564 feet

ARTHROPODA

Crustacea
Cancer anthonyi STIMPSON, 1856 yellow crab
Frequent Depth range: 60 - 430 feet
Cancer gracilis DANA, 1852 slender crab
Frequent Depth range: 60 - 570 feet
Loxorhynchus crispatus STIMPSON, 1875 decorator crab
Frequent Depth: 60 feet
Loxorhynchus grandis STIMPSON, 1857 spider crab
Frequent Depth range: 60 - 126 feet
Pyromaia tuberculata (LOCKINGTON, 1876) spider crab
Frequent Depth range: 60 - 120 feet
Heterocrypta occidentalis (DANA, 1854) elbow crab
Occasional Depth range: 60 - 300 feet
Mursia gaudichaudii (MILNE-EDWARDS, 1837)
Frequent Depth range: 120 - 600 feet
Randallia ornata (RANDALL, 1839)
Frequent Depth range: 60 - 540 feet
Portunus xantusii (STIMPSON, 1860)
Occasional Depth: 60 feet
Portunus sp.
Occasional Depth: 60 feet
Pinnixa longipes (LOCKINGTON, 1877)
Occasional Depth range: 120 - 420 feet
Pleuroncodes planipes STIMPSON, 1860
Frequent Depth range: 174 - 180 feet
Paralithodes sp.
Occasional Depth not recorded
Lopholithodes foraminatus (STIMPSON, 1859)
Occasional Depth range: 516 - 540 feet
Paralithodes interruptus (RANDALL, 1839)
Occasional Depth: 60 feet

- Galathea californiensis* BENEDICT, 1904
Occasional Depth range: 276 - 378 feet
- Crago nigromaculata* (LOCKINGTON, 1877)
Frequent Depth range: 60 - 570 feet
- Crago alaskensis* (RATHBUN, 1902)
Occasional Depth not recorded
- Sicyonia ingentis* BURKENROAD, 1938
Frequent Depth range: 120 - 600 feet
- Pandalus jordani* RATHBUN, 1902
Frequent Depth range: 564 - 600 feet
- Spirontocaris* sp.
Frequent Depth range: 60 - 600 feet
- Penaeus californicus* KINGSLEY, 1878
Occasional Depth not recorded
- Pseudosquilla bigelowi* (SCHMITT, 1940)
Occasional Depth range: 60 - 222 feet

MOLLUSCA

Cephalopoda

- Rossia pacifica* BERRY, 1911 squid
Frequent Depth range: 120 - 600 feet
- Loligo opalescens* BERRY, 1911 squid
Frequent Depth range: 60 - 600 feet
- Octopus* spp. octopus
Frequent Depth range: 60 - 600 feet
- Tectibranchiata sea hares
Frequent Depth range: 60 - 600 feet
- Nudibranchiata sea slug
Frequent Depth range: 60 - 600 feet
- Gastropoda
- Diodora aspera* (ESCHSCHOLTZ, 1833)
Occasional Depth range: 180 - 540 feet
- Puncturella cucullata* (GOULD, 1846)
Occasional Depth range: 240 - 300 feet
- Puncturella cooperi* CARPENTER, 1864
Occasional Depth range: 216 - 466 feet
- Crepidula* sp. slipper shell
Occasional Depth range: 60 - 246 feet
- Acteocina intermedia* WILLET, 1928
Frequent Depth range: 120 - 600 feet
- Philene alba* MATTOX, 1958
Occasional Depth range: 120 - 240 feet
- Turcica caffee* GABB, 1865
Rare Depth range: 192 - 198 feet
- Cidarina cidaris* ADAMS, 1864
Rare Depth range: 252 - 360 feet
- Calliostoma tricolor* GABB, 1865
Frequent Depth range: 60 - 558 feet
- Calliostoma annulatum* (LIGHTFOOT, 1786)
Occasional Depth range: 192 - 300 feet

- Calliostoma gloriosum* DALL, 1871
Rare Depth: 80 feet
- Calliostoma turbinum* DALL, 1895
Rare Depth: 80 feet
- Calliostoma variegatum* CARPENTER, 1864
Rare Depth range: 252 - 324 feet
- Solariella peramabilis* CARPENTER, 1864
Frequent Depth range: 180 - 300 feet
- Sinum scopulosum* (CONRAD, 1849)
Rare Depth range: 60 - 600 feet
- Acteon painei* DALL, 1903
Rare Depth range: 252 - 300 feet
- Acteon punctocaelatus* (CARPENTER, 1864)
Rare Depth range: 210 - 240 feet
- Polinices altus* (DALL, 1909)
Rare Depth: 120 feet
- Polinices draconis* (DALL, 1903)
Occasional Depth range: 60 - 600 feet
- Polinices lewisii* (GOULD, 1847)
Occasional Depth range: 60 - 126 feet
- Polinices reclusianus* (DESHAYES, 1839)
Frequent Depth range: 120 - 180 feet
- Cypraca spadicea* SWAINSON, 1823
Rare Depth: not recorded
- Trivia ritleri* RAYMOND, 1903
Rare Depth range: 276 - 300 feet
- Turbonilla* sp.
Occasional Depth range: 60 - 600 feet
- Balcis micans* (CARPENTER, 1864)
Occasional Depth range: 276 - 300 feet
- Eunaticina oldroydi* (DALL, 1897)
Frequent Depth range: 570 - 588 feet
- Eulima* sp.
Occasional Depth range: 120 - 588 feet
- Epitonium bellistriatum* (CARPENTER, 1864)
Rare Depth range: 54 - 60 feet
- Epitonium* sp.
Rare Depth: 588 feet
- Opalia wroblewskyi* MÖRCH, 1852
Rare Depth range: 276 - 288 feet
- Turritella cooperi* CARPENTER, 1864
Rare Depth: 192 feet
- Erato* sp.
Occasional Depth range: 120 - 228 feet
- Neosimnia catalinensis* BERRY, 1916
Frequent Depth range: 192 - 450 feet
- Bittium interfossa* (CARPENTER, 1864)
Rare Depth: 588 feet
- Bittium subplanatum* BARTSCH, 1911
Rare Depth: 180 feet
- Bittium* sp.
Frequent Depth range: 180 - 600 feet

- Terebra pedroana* DALL, 1908
Occasional Depth range: 60 - 120 feet
- Nassarius cooperi* (FORBES, 1850)
Rare Depth: 180 feet
- Nassarius fossatus* (GOULD, 1850)
Occasional Depth: 60 feet
- Nassarius insculptus* (CARPENTER, 1864)
Frequent Depth range: 180 - 600 feet
- Nassarius mendicus* (GOULD, 1850)
Occasional Depth: 60 feet
- Nassarius perpinguis* (HINDS, 1844)
Occasional Depth range: 60 - 192 feet
- Olivella baetica* CARPENTER, 1864
Occasional Depth range: 60 - 300 feet
- Olivella pyena* BERRY, 1935
Occasional Depth: 60 feet
- Cancellaria cooperi* GABB, 1865
Frequent Depth range: 330 - 588 feet
- Cancellaria crawfordiana* DALL, 1891
Frequent Depth range: 432 - 600 feet
- Mitra idae* MELVILL, 1898
Frequent Depth range: 192 - 300 feet
- Mitrella carinata* (HINDS, 1844)
Rare Depth: 120 feet
- Mitrella gausapata* (GOULD, 1850)
Frequent Depth range: 180 - 420 feet
- Mitrella tuberosa* (CARPENTER, 1864)
Rare Depth: 60 feet
- Amphissa bicolor* DALL, 1892
Rare Depth range: 414 - 420 feet
- Amphissa undata* (CARPENTER, 1864)
Occasional Depth range: 180 - 540 feet
- Shaskyus festivus* (HINDS, 1844)
Frequent Depth range: 60 - 564 feet
- Fusinus barbarensis* (TRASK, 1855)
Occasional Depth range: 180 - 228 feet
- Pteropurpura macropterus* DESHAYES, 1839
Rare Depth range: 66 - 180 feet
- Pteropurpura vokesae* EMERSON, 1964
Occasional Depth range: 60 - 72 feet
- Trophonopsis bentleyi* (DALL, 1908)
Frequent Depth range: 420 - 600 feet
- Trophonopsis lasius* (DALL, 1919)
Rare Depth range: 240 - 300 feet
- Trophonopsis scitulus* (DALL, 1891)
Rare Depth range: 216 - 300 feet
- Trophonopsis triangulatus* (CARPENTER, 1864)
Rare Depth range: 180 - 600 feet
- Ocenebra barbarensis* (GABB, 1865)
Rare Depth: 252 feet
- Kelletia kelletii* (FORBES, 1850)
Frequent Depth range: 60 - 564 feet
- Daphnella clathrata* GABB, 1865
Rare Depth range: 180 - 432 feet
- Forreria belcheri* (HINDS, 1843)
Rare Depth: 60 feet
- Bursa californica* (HINDS, 1843)
Frequent Depth range: 60 - 387 feet
- Conus californicus* HINDS, 1844
Frequent Depth range: 60 - 192 feet
- Megasurcula carpenteriana* (GABB, 1865)
Frequent Depth range: 60 - 600 feet
- Megasurcula stearnsiana* (RAYMOND, 1904)
Occasional Depth range: 216 - 360 feet
- Antiplanes litus* DALL, 1919
Rare Depth: 588 feet
- Antiplanes perversa* (GABB, 1865)
Rare Depth: 588 feet
- Antiplanes* sp.
Rare Depth range: 432 - 444 feet
- Burchia redondoensis* (T. BURCH, 1938)
Occasional Depth: 60 feet
- Elaeocyna empyrosia* (DALL, 1899)
Occasional Depth range: 180 - 420 feet
- Mangelia arteaga* DALL & BARTSCH, 1910
Occasional Depth range: 180 - 420 feet
- Mangelia beta* DALL, 1919
Rare Depth range: 336 - 456 feet
- Clathurella crystallina* GABB, 1865
Rare Depth range: 576 - 600 feet
- Ophiodermella halcyonis* (DALL, 1908)
Rare Depth: 120 feet
- Pelecypoda
- Acila castrensis* HINDS, 1843
Frequent Depth range: 360 - 600 feet
- Nucula tenuis* MONTAGU, 1808
Occasional Depth range: 180 - 588 feet
- Nuculana hamata* (CARPENTER, 1864)
Occasional Depth range: 186 - 600 feet
- Nuculana acuta* (CONRAD, 1832)
Occasional Depth range: 408 - 600 feet
- Yoldia ensifera* DALL, 1897
Frequent Depth range: 336 - 600 feet
- Acquiptecten latiauratus* (CONRAD, 1837)
Occasional Depth range: 60 - 456 feet
- Chlamys hastatus* SOWERBY, 1843
Occasional Depth range: 216 - 228 feet
- Lima hemphilli* HERTLEIN & STRONG, 1946
Occasional Depth range: 60 - 234 feet
- Pecten diegensis* DALL, 1898
Frequent Depth range: 60 - 408 feet
- Cardita ventricosa* GOULD, 1850
Rare Depth: 558 feet

- Cyclopecten vancouverensis* (WHITEAVES, 1886)
Rare Depth range: 60 - 248 feet
- Delectopecten* sp.
Occasional Depth range: 180 - 564 feet
- Anomia peruviana* D'ORBIGNY, 1846
Occasional Depth range: 324 - 330 feet
- Amygdalum pallidulum* (DALL, 1916)
Frequent Depth range: 180 - 600 feet
- Modiolus neglectus* SOOT-RYEN, 1955
Rare Depth: 180 feet
- Solamen columbianum* (DALL, 1897)
Occasional Depth: 180 feet
- Pandora filosa* (CARPENTER, 1864)
Occasional Depth range: 186 - 420 feet
- Solcmya panamensis* DALL, 1908
Occasional Depth range: 252 - 588 feet
- Hiatella arctica* (LINNAEUS, 1767)
Occasional Depth range: 180 - 372 feet
- Lyonsia californica* CONRAD, 1837
Occasional Depth range: 180 - 192 feet
- Thracia trapezoides* CONRAD, 1849
Rare Depth range: 330 - 480 feet
- Thyasira barbarensis* DALL, 1889
Occasional Depth range: 180 - 600 feet
- Solen rosaceus* CARPENTER, 1864
Occasional Depth: 60 feet
- Pseudochama exogyra* (CONRAD, 1837)
Occasional Depth range: 186 - 324 feet
- Pseudochama granti* STRONG, 1934
Occasional Depth range: 198 - 306 feet
- Cuspidaria apodema* DALL, 1916
Frequent Depth range: 180 - 588 feet
- Cuspidaria planetica* DALL, 1908
Frequent Depth range: 234 - 600 feet
- Cuspidaria californica* DALL, 1886
Rare Depth: 336 feet
- Nemocardium centiflosum* (CARPENTER, 1864)
Frequent Depth range: 120 - 444 feet
- Trachycardium quadragenarium* (CONRAD, 1837)
Occasional Depth range: 60 - 192 feet
- Lucinoma annulata* (REEVE, 1850)
Occasional Depth range: 384 - 420 feet
- Lucinoma tenuisculpta* (CARPENTER, 1864)
Occasional Depth range: 316 - 318 feet
- Compsomyx subdiaphana* (CARPENTER, 1864)
Frequent Depth range: 120 - 600 feet
- Cooperella subdiaphana* (CARPENTER, 1864)
Rare Depth: 120 feet
- Gari edentula* (GABB, 1868)
Rare Depth: 120 feet
- Macoma carlottensis* WHITEAVES, 1880
Frequent Depth range: 342 - 600 feet

- Macoma* sp.
Rare Depth range: 330 - 480 feet
- Tellina arenica* HERTLEIN & STRONG, 1949
Occasional Depth range: 300 - 588 feet
- Amphineura
Lepidozona retiporosa (CARPENTER, 1864)
Occasional Depth range: 180 - 600 feet
- Scaphopoda
Dentalium rectius CARPENTER, 1864
Frequent Depth range: 360 - 600 feet
- Dentalium vallicolens* RAYMOND, 1904
Rare Depth range: 384 - 420 feet

BRACHIOPODA

- Glottidia alba* (HINDS, 1844)
Rare Depth range: 120 - 174 feet
- Terebratalia occidentalis* (DALL, 1871)
Occasional Depth range: 216 - 378 feet
- Laqueus californicus* (COCH, 1848)
Rare Depth range: 384 - 432 feet

ECHINODERMATA

- Astroidea
Astropecten sp.
Frequent Depth range: 60 - 600 feet
Large numbers at times
- Mediaster aequalis* STIMPSON, 1857
Frequent Depth range: 120 - 432 feet
- Astrometis* sp.
Occasional Depth: 300 feet
- Pisaster brevispinus* (STIMPSON, 1857)
Frequent Depth range: 60 - 420 feet
- Luidia foliolata* GRUBE, 1866
Occasional Depth range: 60 - 564 feet
- Rathbunaster californicus* FISHER, 1906
Occasional Depth range: 60 - 240 feet
- Ophiuroidea
Frequent Depth range: 114 - 600 feet
- Echinoidea
Allocentrotus fragilis JACKSON, 1912
Frequent Depth range: 219 - 570 feet
Large numbers at times
- Lytechinus anamesus* H. L. CLARK, 1912
Frequent Depth range: 174 - 436 feet
Large numbers at times
- Strongylocentrotus* sp.
Occasional Depth range: 114 - 252 feet
- Brisaster townsendi* (AGASSIZ, 1898)
Frequent Depth range: 60 - 540 feet
Large numbers at times

Crinoidea

Florometra perplexa A. H. CLARK, 1907

Frequent Depth range: 60 - 387 feet

Holothuroidea

Stichopus spp.

Frequent Depth range: 60 - 600 feet

Large numbers at times

TUNICATA

Salpa spp.

Frequent Depth range: 60 - 378 feet

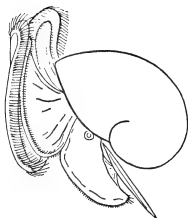
Large numbers at times

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Pelecypod-Sediment Association in Tomales Bay, California

BY

DON MAURER

Shellfish Laboratory, University of Delaware, Lewes, Delaware 19958¹

(1 Map; 3 Tables)

INTRODUCTION

THIS STUDY WAS UNDERTAKEN to determine whether there was an association between distribution, abundance and size of pelecypods and sediment particle size. Research was conducted during the summers of 1961 through 1963 at the Pacific Marine station in Tomales Bay, located in Marin County, California between 38° 14'00" N Latitude, 122° 58'35" W Longitude and 38° 05' 30" N Latitude, 122° 49'40" W Longitude. The species under study, *Tellina buttoni* DALL, 1900, *T. salmonea* (CARPENTER, 1864), *Mysella tumida* (CARPENTER, 1864) *Lyonsia californica* CONRAD, 1837, and *Transennella tantilla* (GOULD, 1852) were selected because they are numerous, widely distributed and occur in a variety of sediment types in Tomales Bay. Most research on bivalve-sediment relationships has been chiefly concerned with species commonly collected by dredges. Such collections mix different sediment types and tend to confuse natural pelecypod-substrate associations. The present study differs from earlier investigations in that samples were collected with a quantitative grab which assures a collection of bivalves from the sediment in which they live, an important prerequisite for the determination of pelecypod-sediment associations.

The purpose of the paper is to report the results of an investigation on bivalve-sediment relationships in Tomales Bay. Results indicate that distribution and abundance of all species except *Transennella tantilla* appear to be strongly influenced by sediment type. The average size of the tellinids and *Mysella tumida* is statistically associated with sediment particle size, whereas a corresponding significant association did not exist for *Lyonsia californica* and *Tr. tantilla*.

ALLEN (1963) provides the most recent comprehensive review of studies concerning distribution, abundance and growth of bivalves related to substrate influences. Associ-

ation of tellinid species with sediment type has been reported in California by several authors. PACKARD (1918) observed the occurrence of *Tellina buttoni* and *T. salmonea* in mud and sand and of the latter in gravel, and sand-shell substrates of San Francisco Bay. REISH (1961) found *T. buttoni* in gray clay of a boat harbor in southern California. RICKETTS & CALVIN (1962) presented a sketch map which showed a *Tellina* sand facies in Tomales Bay and JONES (1964) stated that species of *Tellina* were common benthic mollusks living in sand bottoms off southern California. As regards the other species, OLDROYD (1924) and KEEP (1935) indicated that *Transennella tantilla* lives in fine sand and *Lyonsia californica* occurs in muds of bays. REISH (1961) included *L. californica* in a species list of mollusks that were found in clay. However, these studies were primarily concerned with reporting the occurrence and relative number of these species in a general sediment type rather than defining any quantitative aspects of bivalve-sediment relationships. Furthermore, no studies are available on these species concerning their size related to sediment type.

MATERIALS AND METHODS

During the months of June, July and August of 1961 through 1963, 142 pelecypod-sediment samples were obtained aboard the R/V *Bios Pacifica* with a 0.1 square meter van Veen grab. At each collecting site, a sediment sample was taken, and the position, depth of water, volume of grab and a brief description of flora and fauna were recorded. Samples were washed aboard through a screen of 1.0 mm mesh and the residue was placed in jars with 5 to 10% formalin. Pelecypods were sorted, identified, and counted in the laboratory.

Measurements were taken on 3297 individuals. Maximum anterior-posterior dimension was selected to represent the size of clams. This measurement is convenient

¹ Contribution No. 55, University of Delaware Marine Laboratories

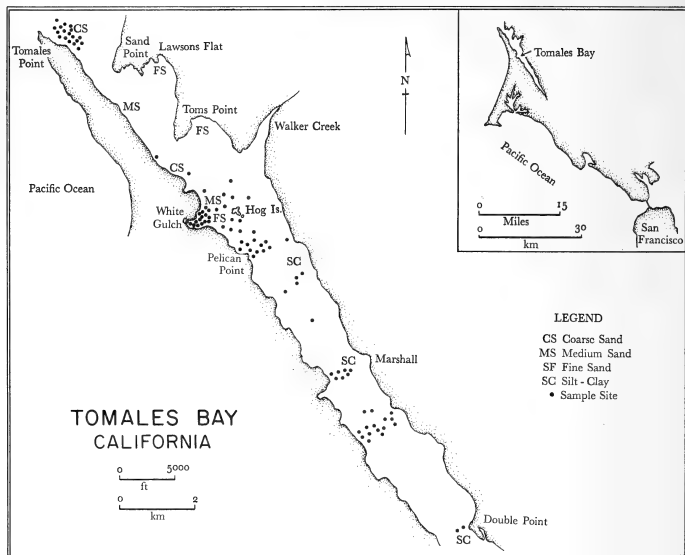


Figure 1

Index Map of Tomales Bay, California.
Sediment Distribution and Sample Sites.

and has been commonly used as an indication of size (KRISTENSEN, 1957). A vernier caliper was used to measure *Lyonsia californica* and larger specimens of tellinids. An ocular micrometer and microscope reticle were used on *Mysella tumida*, *Transennella tantilla* and smaller tellinids. Measurements with all devices had an operational error of ± 0.02 mm.

Sediments were analyzed by standard sieve analyses. Pipette analyses were required for silt and clay samples. A measure of the 20th, 50th, and 80th sediment percentiles, the percentage of silt and clay, the sorting coefficient (80th minus 20th divided by 50th) were determined. Among 142 sediment samples 22%, 59%, 4%, and 14%, were mud, fine, medium, and coarse sand

respectively (Table 1). Sediment types are defined in this table.

JOHNSON (1965) has summarized the hydrographic conditions of the bay. These factors together with the substrate are important features in the ecology of bivalves. It is often difficult to recognize the effect or to isolate the importance of one ecological factor to the exclusion of others. In order to assess the effect of sediment type on pelecypod ecology in Tomales Bay an intensive study of animal-sediment relationships was also conducted in White Gulch. White Gulch is a small cove 4.8 km from the mouth of the bay (Map, Figure 1). The cove is naturally suited for such studies in that it contains various sediment types and has a relatively narrow range of hydrographic features compared to the wider range of conditions throughout the bay. MERTES (1962) has shown that subtidal conditions in White Gulch are homogeneous with regard to water temperature and salinity. If pelecypod-sediment associations are relatively uni-

form, then the ecological significance of sediment can be extended to similar associations found in the bay at large. A more detailed account of methods can be found in MAURER (1964).

DISTRIBUTION AND ABUNDANCE

In Tomales Bay *Tellina buttoni* has been collected from depths of 0.6 to 18.9 m and lives mainly in depths of 4.6 to 10.6 m. Locally *T. buttoni* occurs in the northern part of the bay from Sand Point to Pelican Point. South of Pelican Point it has been taken occasionally from holes and channels that lie along the western margin of the bay. This tellinid lives in sediment that varies from mud through coarse sand and, in rare cases, pebbles. It occurs most frequently and in greatest numbers in fine sediment. Ninety-one percent of *T. buttoni* were found in fine sand (Table 1) with 5 to 30% silt and clay. On the northeastern margin of White Gulch *T. buttoni* lives in sediment that contains as much as 50% silt and clay. Fine sediment here is due to the gradual decay of eel grass and trapping of particulate matter by clusters of *Zostera*.

Tellina salmonea dwells most frequently in depths between 3.0 and 7.9 m and it has the same depth range as *T. buttoni*. Although the salmon tellinid has not been collected intertidally, subtidal sampling and presence of many shells washed ashore on a beach north of Sand Point indicate that a large population lives in or just beyond the surf zone. *Tellina salmonea* ranges from the open ocean south to Pelican Point. Distribution south of Pelican Point agrees with that of *T. buttoni*. *Tellina salmonea* may inhabit fine sand; however, it occurs most frequently and in greatest numbers in coarse sediment with less than 5% silt and clay. Sixty percent of *T. salmonea* were found in coarse sand with 29% and 11% in fine and medium sand respectively (Table 1).

Range of depth of *Myssella tumida* is from the intertidal zone to 10.6 m though this species more often inhabits depths from 1.2 to 9.1 m. *Myssella tumida* ranges from Toms Point to south of Pelican Point. South of Pelican Point distribution seems to be restricted to the same submarine topography that contains the tellinids. In this southern portion within the central axis of the bay, *M. tumida* is replaced by *M. ferruginosa* (DALL, 1916.) The former species lives in mud and fine sand and occasionally in medium sand, but typically inhabits fine sand with 10 to 30% silt and clay. Ninety-eight percent of *M. tumida* were taken from fine sand (Table 1). On the other hand, *M. ferruginosa* lives characteristically in mud with 70 to 100% silt and clay and was infrequently

Table 1

Abundance of Five Species of Bivalves in Different Sediment Types

	Mud (Silt & Clay) < 0.063 mm	Fine Sand > 0.063 mm < 0.250 mm	Medium Sand > 0.250 mm < 0.50 mm	Coarse Sand > 0.50 mm	Total
Number of Sediment Samples	31	85	6	20	142
Percent of Sediment Samples	22	59	4	14	
<i>Tellina buttoni</i>					
Number of Clams	42	1049	53	9	1153
Percent of Clams	4	91	5	0.8	
<i>Tellina salmonea</i>					
Number of Clams	-	207	78	422	707
Percent of Clams	-	29	11	60	
<i>Myssella tumida</i>					
Number of Clams	6	308	-	-	314
Percent of Clams	2	98	-	-	
<i>Transennella tantilla</i>					
Number of Clams	592	160	33	170	955
Percent of Clams	62	17	3	18	
<i>Lyonsia californica</i>					
Number of Clams	102	66	-	-	168
Percent of Clams	61	39	-	-	
Total:					3297

The measurements which define sediment type refer to median particle size.

Table 2
Pelecypod and Sediment Measurements

Species	Clam Size in mm		Median Particle Size mm or % Silt & Clay		Number Samples	Average Clam Size in Relation to Median Particle Size	
	Range	Average	Range	Average		Sediment mm	Clam mm
<i>Tellina buttoni</i>	1.9 - 18.5	6.5	0.063 - 0.830	0.165	38	< 0.154	5.9
					38	> 0.154	7.2
<i>Tellina salmonea</i>	2.0 - 18.7	9.4	0.113 - 2.090	0.634	19	< 0.370	6.0
					19	> 0.370	11.7
<i>Myssella tumida</i>	1.6 - 3.8	2.7	0.052 - 0.190	0.132	18	< 0.122	2.8
					18	> 0.122	2.6
<i>Transennella tantilla</i>	1.5 - 9.4	4.3	100% to pebbles	43.1%	18	< 0.177	4.4
					18	> 0.177	4.3
<i>Lyonsia californica</i>	4.5 - 38.5	13.7	10.7% - 98.4%	86.5%	19	-	-

found in sand. In White Gulch *M. tumida* is numerous in *Zostera* beds and occurs often with *Tellina buttoni*.

Lyonsia californica was collected from depths of 1.2 to 13.7 m and is taken more commonly from 3.0 to 9.1 m. It ranges from just north of White Gulch to south of Double Point. This bivalve has been obtained almost exclusively from mud and fine sand, and when it occurs in White Gulch, it is collected from very fine sand. It lives essentially in sediment with 80 to 100% silt and clay and is characteristic of the southern two-thirds of the bay or of more northern localities where high concentrations of silt and clay accumulate in protected coves. Sixty-one percent and 39% of *L. californica* were collected from mud and fine sand respectively (Table 1). Among the 5 species it shows the most restricted occurrence in fine sediment.

Transennella tantilla ranges from intertidal locations to the deepest (19.9 m) holes in the bay. The species may occur intertidally in great numbers at Lawsons Flat and White Gulch, although its occurrence is sporadic and seems to fluctuate like populations of *Donax*. Subtidally it generally inhabits depths from 3.0 to 9.1 m. Contrary to the distribution and abundance of the other 4 species *Tr. tantilla* is one of the most ubiquitous clams in the bay. It was found recently in a rocky intertidal area on the ocean side of Tomales Point and its range extends south of Double Point within the bay. This venerid occurs in channels and shoals from Hog Island northwards to Lawsons Flat and throughout the White Gulch area. Its greatest numbers and frequency are seen in mud. Sixty-two percent of *Tr. tantilla* were gathered from mud, while 18%, 17%, and 3% were collected from coarse sand, fine

sand, and medium sand respectively (Table 1). In White Gulch, *Tr. tantilla* occurs throughout the range of sediment types.

SIZE ANALYSIS

In addition to distribution and abundance another pelecypod-sediment relationship was recognized. From Table 2 it can be inferred that there is some association between the size of tellinids and sediment particle size. For example, the average size of 19 samples of *Tellina salmonea* from sediment with a median size less than 0.370 mm is 6.0 mm, whereas the average size of 19 samples from sediment with median size greater than 0.370 mm is 11.7 mm.

To determine whether these relationships were significant, a hypothesis was posed and tested statistically. The hypothesis, which defines an association between a dependent and independent variable, was that pelecypod size is associated with sediment particle size. Since bivalve and sediment sizes may not assume a bivariate normal distribution a nonparametric statistic, the Kendall Correlation Coefficient, was applied. HEDGPETH (1957) cautioned "that many of the data of ecology are non-parametric and hence not amenable to parametric tests,..." According to SIEGEL (1956) the Kendall Correlation Coefficient does not make any assumptions concerning the distributional function. For each sample an average bivalve size was correlated with a sediment measurement (20th, 50th, and 80th sediment percentiles, sorting coefficient, percent of silt and clay) and depth of water. From this a correlation coefficient was obtained and its

probability was determined. Level of significance is 0.05 for all analyses.

If size-frequency distributions are bimodal or polymodal and standard deviations are high, average size can be misleading as an estimate of central tendency. Histograms of bivalve size indicated that, in most samples, variance was relatively low and that there were only a few irregu-

lar distributions. As a check on the use of average size the median pelecypod size of some samples was correlated with a sediment particle measure. Results were comparable to those analyses in which the average clam size was used. However, average size was preferred because:

(1) samples were generally large enough not to be unduly influenced by extreme values; (2) average size

Table 3
Summary of Statistical Analyses

	Sediment Percentiles			Sorting Coef.	% Silt-Clay	Water Depth
	20th	50th	80th			
<i>Tellina buttoni</i>						
1 White Gulch						
Correlation Coefficient	0.394	0.394	0.424	0.348	-0.576	0.394
Probability	0.038*	0.038*	0.027*	0.058-	0.005*	0.038*
Samples (Specimens)	62(828)	IBID	IBID	IBID	58(870)	62(828)
2 Tomales Bay						
Correlation Coefficient	0.667	0.538	0.461	-0.460	-0.187	0.026
Probability	0.001*	0.005*	0.014*	0.026*	0.176-	0.452-
Samples (Specimens)	13(241)	IBID	IBID	IBID	14(283)	13(241)
<i>Tellina salmonea</i>						
3 White Gulch						
Correlation Coefficient	0.286	0.786	0.643	0.571	-0.429	0.357
Probability	0.199-	0.003*	0.016*	0.031*	0.089-	0.138-
Samples (Specimens)	16(144)	IBID	IBID	IBID	IBID	IBID
4 Tomales Bay						
Correlation Coefficient	0.636	0.673	0.636	0.418	-0.163	0.079
Probability	0.003*	0.002*	0.003*	0.037*	0.245-	0.500-
Samples (Specimens)	22(563)	IBID	IBID	IBID	IBID	IBID
<i>Transennella tantilla</i>						
5 White Gulch						
Correlation Coefficient	0.238	0.095	0.333	0.333	0.143	0.238
Probability	0.281-	0.430-	0.191-	0.191-	0.386-	0.281-
Samples (Specimens)	13(97)	IBID	IBID	IBID	IBID	IBID
6 Tomales Bay						
Correlation Coefficient	0.143	0.107	0.286	-0.071	0.030	0.152
Probability	0.360-	0.406-	0.199-	0.452-	0.448-	0.248-
Samples (Specimens)	8(266)	IBID	IBID	IBID	23(858)	23(858)
<i>Myella tumida</i>						
7 White Gulch						
Correlation Coefficient	-0.697	-0.515	-0.273	0.303	0.227	-0.500
Probability	0.001*	0.010*	0.108-	0.085-	0.151-	0.012*
Samples (Specimens)	36(297)	IBID	IBID	IBID	37(314)	36(297)
<i>Lyonsia californica</i>						
8 Tomales Bay						
Correlation Coefficient					0.398	0.444
Probability					0.090-	0.060-
Samples (Specimens)					19(168)	19(168)

* Statistically significant at 0.05

- Not statistically significant at 0.05

of large numbers of specimens is easier to calculate than median or mode which require additional manipulation of raw data to define; (3) small samples contain insufficient entries to form clusters and so the mode is indeterminate. In such cases the mode can not be used and unless the average is applied, information may be lost.

For *Tellina buttoni*, *T. salmonea* and *Transennella tantilla* the null hypothesis is that there is no association between increasing pelecypod size and increasing sediment particle size, whereas the null hypothesis for *Mysella tumida* and *Lyonsia californica* is that there is no association between decreasing pelecypod size and increasing sediment particle size.

Table 3 indicates that the average size of *Tellina buttoni* in the bay and White Gulch is, in general, significantly associated with sediment particle size. In White Gulch the highest correlation is the 80th sediment percentile and the highest correlation in the bay is the 20th sediment percentile. For *T. salmonea* a significant association was found in the bay and White Gulch and its highest correlation is the 50th sediment percentile in both areas. The average size of *Mysella tumida* is also significantly associated with particle size. This species was not collected in sufficient numbers throughout the bay to be compared statistically with samples from White Gulch and therefore analyses were only made for samples from the latter area (Table 3). In contrast to the tellinids, the correlation of *M. tumida* is significant in a negative direction. With *Transennella tantilla* the average size is not significantly associated with particle size. Finally, since *Lyonsia californica* occurs almost exclusively in fine sediment its average size was correlated only with percent of silt and clay. The correlation coefficient was not significant.

DISCUSSION

In the northern part of the bay, Sand Point to White Gulch, sediment type can be characterized as a sandy substrate, with medium and coarse sand in the channels and off headlands, and fine sand in protected coves and shoals. The stretch from White Gulch to Pelican Point represents a transitional area as sand size becomes finer and increases in organic material content. In the transition area the occurrence of all five species overlaps. Pelican Point affords an excellent physiographic boundary for distribution patterns as it marks the beginning of the "mud line" or local sedimentary threshold in Tomales Bay. South of this point the substrate contains 70 to 100%

silt and clay. Small patches of coarse sand and pebbles may occur off headlands, but these are usually confined to the western shore. Occasional beds of fragmented *Ostrea lurida* shells are present between Marshall and Double Point. Based on intensive sediment sampling it was found that fine sand actually extends in tongues slightly farther south than Pelican Point on both sides of the bay (personal communication, Dr. C. C. Daetwyler).

The distribution of the species under study and the majority of subtidal pelecypods in the bay responds in a very sensitive fashion to the mud line. For example, the tellinids and *Mysella tumida* range essentially from the northern part through the transitional area and stop abruptly at the mud line. *Tellina buttoni* occurs in a wider range of sediment than *T. salmonea*. The former is best represented in fine sand with some organic material, while the latter finds its maximum development in clean, coarse sand. A few specimens of *Lyonsia californica* were found in White Gulch, yet it is almost exclusively restricted to sediment (70 to 100% silt and clay) south of Pelican Point. Distribution and abundance of *Transennella tantilla* is an exception as it appears to be uninfluenced by sediment type.

Concerning bivalve size and sediment size only the tellinids and *Mysella tumida* show any significant associations. In general, as sediment particle size increases, size of the tellinids living in those sediments increases. This association is so marked that it can be observed in the field for both tellinids. Not so with *M. tumida*, for the difference in size between this mollusk in finer and coarser sediment is too small for detection in the field. Until statistical analyses were made it was unknown that the size of *M. tumida* decreases as particle size increases.

It should be emphasized for at least the tellinids and *Transennella tantilla* that sediment associations in White Gulch are consistent with those found throughout the bay. If, as previously suggested, pelecypod-sediment associations exist where hydrographic conditions are relatively uniform, then the ecological importance of sediment to similar bivalve associations in the bay at large can be confidently asserted. In passing, the largest forms and greatest numbers of *Tellina salmonea* occur north of Sand Point in pebbles and shell-sand and are commonly twice the size of individuals in medium and coarse sand south of the point. Here the influence of the ocean is unmistakable. Nevertheless, samples collected in close proximity to that area were shown statistically to be drawn from two different populations. Particle size was the striking environmental factor that differed. Although there were insufficient numbers of *Mysella tumida* and *Lyonsia californica* to compare sediment associations from

White Gulch to the bay, both species were obviously best developed in a specific sediment type, fine sand for the former and mud for the latter.

Work by SWAN (1952), PRATT (1953), PRATT & CAMPBELL (1956), WELLS (1957), and PEARCE (1965) with other bivalves support the view that there can be causal relationship between bivalve distribution, abundance, size and sediment type. MAURER (1967 a) was concerned with the biological significance of sediment to pelecypods. Working with the same species except *Lionia californica*, MAURER, (1967 a, 1967 b, 1967 c) provided experimental evidence to indicate that the effect of turbidity and sediment as a food source were important factors influencing bivalve-sediment associations. The writer submits that sediment type may be a limiting factor in determining the distribution and abundance of *Tellina buttoni*, *T. salmonea*, *Myssella tumida*, and *L. californica* in Tomales Bay. Moreover, the size of the tellinids and *Myssella tumida* appears to be influenced by sediment. No explanation for the significant negative correlation coefficient obtained with *M. tumida* is offered at the present, and no noteworthy bivalve-sediment associations were recognized with *Tr. tantilla*. Although the effect of some important life-cycle aspects (life span, reproductive periods, size of settling larvae, larval substrate preference) remain to be studied in order to more completely evaluate the proposed sediment relationships, the writer asserts that the broad outline and definition of the pelecypod-sediment associations are valid.

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Studies on the *Mytilus edulis* Community
in Alamitos Bay, California. - IV.
Seasonal Variation
in Gametes from Different Regions in the Bay

BY

DONALD R. MOORE

AND

DONALD J. REISH

Department of Biology, California State College at Long Beach, California 90804

(5 Text figures; 1 Table)

INTRODUCTION

THE BAY MUSSEL, *Mytilus edulis* LINNAEUS, 1758, is distributed throughout Alamitos Bay, California (Figure 1). It is especially abundant wherever floating boat docks occur, but in the upper reaches of the bay, notably Colorado Lagoon and Cerritos Channel, the number of specimens decreases. The chlorinity of the bay is uniform throughout except immediately following infrequent winter rains (STONE & REISH, 1965). Since formation of the gametes and subsequent fertilization and development is essentially for repopulation, and since *M. edulis* is distributed throughout the bay, the authors were curious whether or not the mussels will produce gametes in all areas of their distribution in the bay, and, if so, would they be produced at the same or at different times of the year. In other words, is the reproductive population in a limited area of the bay surrounded by a vegetative, non-reproductive population of *M. edulis*? Gonadal tissue was examined periodically from 4 areas of the bay to determine whether or not seasonal differences occurred within an area and from area to area.

The seasonal reproduction of *Mytilus edulis* has been studied in the past by the analysis of gonads (FIELD, 1922), CHIPPERFIELD (1953), SUGIURA (1959), and by

seasonal attachment of larvae by ENGLE & LOOSANOFF (1944), GRAHAM & GAY (1945), CHIPPERFIELD (1953), and LOOSANOFF & DAVIS (1963), and REISH (1964a). CHIPPERFIELD indicated sexually mature mussels occurred from mid-April to the end of May in British waters. Gamete maturation began when the water temperatures reached 7° C and spawning commenced while the temperatures were rising from 9½° to 12½° C. In warmer Japanese waters, SUGIURA (1959) noted gamete maturation occurred when the water temperature dropped to 18° C in the fall. Larval settlement took place in late spring and early summer in Connecticut (ENGLE & LOOSANOFF, 1944), in central California (GRAHAM & GAY, 1945), and in England (CHIPPERFIELD, 1953). However, in Alamitos Bay larval settlement occurred in late winter and early spring when the water temperatures were not below 13° C (REISH, 1964a).

Since the previous studies on seasonal reproduction in *Mytilus edulis* have been carried out in more northern latitudes, the purpose of this study was to determine whether or not a seasonal variation in the maturity of the ova and sperm occurred in Alamitos Bay. An additional purpose of this study was to investigate whether or not variations in the degree of intensity of reproduction existed in populations from different areas of the bay.

MATERIAL AND METHODS

Monthly samples of *Mytilus edulis* were collected from 4 localities within Alamitos Bay, Long Beach, California, from November, 1964 through July, 1966 (Figure 1). Subsurface water temperatures were taken at the time of collection. Water samples were taken for chlorinity determinations during the first year. Since this value varies only during periods of rainfall (STONE & REISH, 1965),

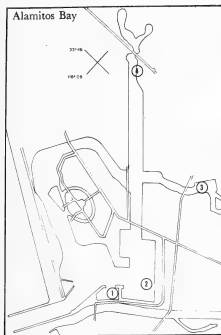


Figure 1

Map of Alamitos Bay, California, showing Station Locations

the chlorinity data were not included herein because they were of little significance to this report. Samples were taken from Stations 1 and 2 at the same time and at Stations 3 and 4 one or two weeks later.

Stations 1, 3, and 4 represented extremes in the distribution of the population where sufficient numbers of specimens were present. Station 2 is in an intermediate location where earlier studies on *Mytilus edulis* were conducted (REISH, 1964a, 1964b). Occasional specimens occur along the rock jetty at the channel entrance and up the channel from Station 3, but there was not a sufficient number of specimens to permit analysis. All mussels were collected from floating boat docks; thus, the specimens were always covered with water.

The specimens were brought back to the laboratory to ascertain the degree of gamete development. Smears

were made of gonadal tissues, and the classification system of CHIPPERFIELD (1953) was followed as:

Stage 0. Sex unknown (indeterminate); no follicles present.

Stage 1. Follicles present; sperm mother cells and spermatids present; a few small oocytes seen.

Stage 2. Sperm present, but not motile; ova not fully developed, wrinkled, and would not become spherical when placed in sea water; no fertilization.

Stage 3. Sperm motile; ova fully developed and became spherical when placed in sea water; fertilization.

Recent spent stage: A few residual gametes left in follicles.

Ten individuals of each sex were selected for microscopic examination of gonadal smears. Mature males could be distinguished by the cream or yellowish-cream colored gonads, and mature females by their apricot or red-brown colored gonads. The colors of the gonads were light orange or light yellow in stages 1 and 2 of both sexes. Gonadal smears were made of each specimen and the stage of development was noted. A separate count of indeterminates or recently spent mussels was made.

An average stage of gamete development was calculated for each male and female each month by totalling the figures for the different stages observed and dividing the number of individuals examined. The number of indeterminates was totalled separately.

DATA

The data for the seasonal variation in male and female gamete development over the 20-month period of observation are presented in Table 1 and Figures 2 to 5. The range and average stage of gametogenesis for each sex are presented by date for the 4 stations in Table 1. The data are summarized graphically by station for each sex for each period of observation as the average stage of gamete development. These averages are based on 10 specimens of each sex except when a large number of indeterminates was encountered. The number of indeterminates and the water temperature are also included in each graph.

The data show that some degree of gametogenesis occurred in both sexes to a greater or lesser extent at all stations throughout the entire period of observation from November 1964 through July 1966. However, the degree of gametogenesis fluctuated seasonally in both males and females. The higher levels of gamete development were observed during the late fall and early winter months.

Mussels with mature gametes decreased in numbers from March to the end of July each year. The greatest number of indeterminates was observed from May to October.

SEASONAL VARIATION IN MALE GAMETOGENESIS

Mature sperm were present in some specimens at all 4 stations throughout the period of observation except at Station 2 in March and April 1965 and at station 4 in July 1966 (Table 1). However, a seasonal variation in the average stage of gamete development occurred at all stations, and, furthermore, variations in the degree of gamete maturity from station to station were noted (Figures 2 to 5).

A total of 68 samples was taken from all stations during the 20 months of study; of these 14 (or 21%)

of the samples of males were composed entirely of mussels at stage 3 of gamete development. Six of these 14 samples were observed at Station 1, 3 each at Stations 2 and 3, and 2 at Station 4. Only 3 samples, or 4%, of the 68 samples did not have any individuals at stage 3 of gamete development. The overall average stage of male gamete development was 2.6, 2.5, 2.5, and 2.4 for Stations 1 to 4, respectively. The length of time during which the average gamete stage of development was high (over 2.5) and longer was at Stations 1 and 2.

An inverse relationship between the male gamete stage and water temperature was observed at all stations (Figures 2 to 5). The low point in the average stage of male gamete development occurred from the months of March to August when the water temperature rose from 17° C to 24° C. The high point in the average stage of male gamete development occurred from October to February when the water temperature dropped from 24° to 13° C.

Table 1

Seasonal Changes in the Stages of Gamete Development in Males and Females of *Mytilus edulis* Based on a Numerical Scale of 1 to 3¹

Date	Station 1				Station 2				Station 3				Station 4			
	Males		Females		Males		Females		Males		Females		Males		Females	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
1964																
November 18, 24	3	3.0	1-2	1.9	2-3	2.8	1-3	1.8	1-3	2.3	1-2	1.8	2-3	2.4	1-3	1.8
December 2, 9	3	3.0	1	1.0	2-3	2.8	1-2	1.1	2-3	2.8	1-3	1.7	3	3.0	1-2	1.1
1965																
January 6, 13	3	3.0	1-2	1.2	1-3	2.6	1-2	1.6	3	3.0	1-2	1.3	2-3	2.9	1	1.0
February 3, 10	3	3.0	1-2	1.0	2-3	2.7	1-2	1.2	1-3	2.8	1-3	1.3	2-3	2.7	1	1.0
March 3, 17	1-3	2.2	1-2	1.1	1-2	1.5	1-2	1.2	1-3	2.3	1-2	1.5	1-3	2.1	1	1.0
April 7, 21	1-3	1.6	1	1.0	1-2	1.5	1	1.0	1-3	2.5	1-2	1.3	1-3	2.2	1-2	1.1
May 5, 12	1-3	2.3	1-2	1.1	1-3	2.5	1	1.0	1-3	2.3	1-2	1.4	2-3	2.4	1	1.0
June 2	1-3	2.3	1	1.0									1-3	2.1	1-2	1.1
July 12, 19	1-3	2.4	1-2	1.1	1-3	2.0	1-2	1.2	1-3	2.1	1-2	1.3	1-3	2.2	1-2	1.3
August 2, 16	1-3	2.0	1-2	1.2	1-3	2.3	1-2	1.6					1-3	2.1	1-2	1.1
September 9, 15	1-3	2.3	1-2	1.5	2-3	2.9	1-2	1.3	1-3	2.3	1-2	1.5	1-3	2.3	1-3	1.2
October 6, 13	3	3.0	1-2	1.3	3	3.0	1-2	1.2	3	3.0	1-2	1.4	2-3	2.6	1-2	1.4
November 10	2-3	2.9	1-2	1.3	2-3	2.9	1-2	1.4					3	3.0	1-2	1.5
December 1, 8	3	3.0	1-2	1.3	2-3	2.9	1-2	1.4	2-3	2.9	1-3	1.9	2-3	2.8	1-2	1.1
1966																
February 2	2-3	2.9	1-3	1.8	2-3	2.9	2-3	2.4	3	3.0	1-3	1.8	1-3	2.1	1-2	1.2
March 17, 22	2-3	2.8	1-2	1.1	3	3.0	1-3	1.6	2-3	2.9	1-3	1.6	2-3	2.7	1-2	1.2
May 3, 31	1-3	2.6	1-2	1.1	3	3.0	1-2	1.3	1-3	2.0	1-3	2.3	1-3	2.6	1	1.0
July 12	1-3	1.8	1	1.0	1-3	2.2	1-2	1.2	1-3	1.4	1	1.0	1-2	1.4	1-2	1.3

¹ Based on analysis of 10 specimens of each sex whenever possible. The analysis of less than 10 specimens occurred frequently during the summer months when the number of indeterminates was higher.

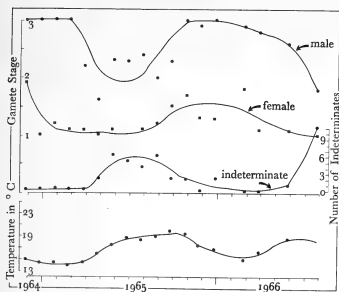


Figure 2

The seasonal variation in the average stage of male and female gamete development, the number of indeterminates, and water temperature at Station 1

SEASONAL VARIATION IN FEMALE GAMETOGENESIS

Mature ova were present in some of the specimens in only 12 of the 68 samples analyzed and 6 of these were from Station 3 (Table 1). These mature ova were ob-

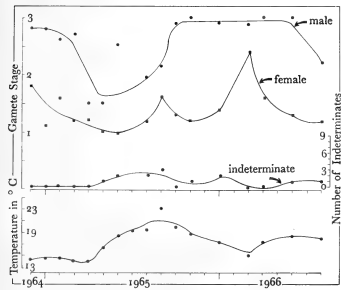


Figure 3

The seasonal variation in the average stage of male and female gamete development, the number of indeterminates, and water temperature at Station 2

served during some of the months between November and March except one instance in September 1965 at Station 4 and one in May 1966 at Station 4. A seasonal variation in the average stage of gamete development was noted at all stations during the 20-month observational period. While a considerable variation occurred from station to station, especially regarding the extent of the period of higher averages, the average stage of female gamete development was highest from November through February and lowest from about March through September (Figures 2 to 5).

Of the 68 samples analyzed for the stage of female gamete development 12 (or 18%) had specimens only in stage 1 or the follicle stage. Stage 1 was always observed in some of the specimens in a sample except at Station 2 in February 1966. The overall stage of female gamete development was 1.2, 1.4, 1.5, and 1.2 for stations 1 to 4, respectively. The length of time during which the average gamete stage of development was highest (over 1.7) was longer at Station 3 and shortest at Station 4.

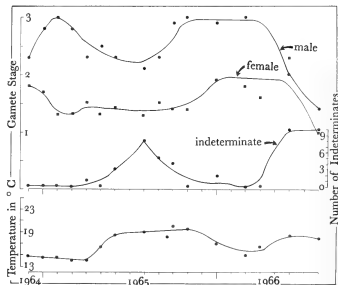


Figure 4

The seasonal variation in the average stage of male and female gamete development, the number of indeterminates, and water temperature at Station 3

NUMBER OF INDETERMINATE INDIVIDUALS

The fluctuation in the number of indeterminates observed correlated inversely with the seasonal aspect of male and female gamete development. The number of indeterminates increased between April and August when the average level of gamete development was decreasing. The

total number of indeterminates observed during the study was 31, 13, 43, and 36 at Stations 1 to 4, respectively.

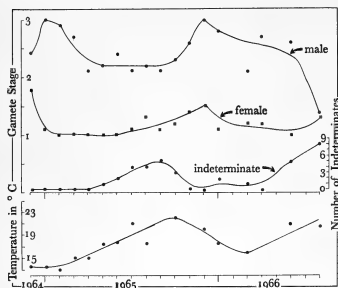


Figure 5

The seasonal variation in the average stage of male and female gamete development, the number of indeterminates, and water temperature at Station 4

DISCUSSION

The occurrence of mature gametes in *Mytilus edulis* reached a peak at all stations in the fall and early winter months in Alamitos Bay when the water temperatures decreased from 20° to 21° C in September to 15° C in December. Some stages of gametogenesis were observed in both sexes at all stations during the period of 20 months. More advanced stages were observed for longer periods of time in males than in females (Figures 2 to 5). These observations were similar to those reported by SUGIURA (1959) for *M. edulis* in Japanese waters. Sexually mature mussels were abundant in October and November when the water temperature was 18° C and least abundant during August when temperatures reached 28½° C. Both of these observations are different to what was observed by CHIPPERFIELD (1953) in colder British waters. Gametes matured when the water temperatures rose above 7° C and spawning occurred from 2 to 6 weeks from mid-April through May when temperatures rose from 9½° to 12½° C. After spawning, CHIPPERFIELD noted a period of 2 to 3 months when all mussels were indeterminate.

Apparently, in the colder British waters the development of gametes and spawning are limited by water

temperatures to a greater extent than in the more temperate waters of Japan and southern California. The period of time in which mature gametes are present is considerably longer in Japanese and southern California waters. Recovery from spawning with the subsequent re-development of the next generation of gametes occurs faster in the Japanese and southern Californian populations of *Mytilus edulis*. Longer reproductive seasons were found in the sea urchin *Strongylocentrotus purpuratus* (STIMPSON) which were collected from warmer waters of lower latitudes than from colder waters of higher latitudes (BOOLOOTIAN & GIESE, 1959).

Gonad analyses could not be made from specimens of *Mytilus edulis* collected at the extremes of its distribution within Alamitos Bay because of insufficient numbers being present. Some differences, indicated by trends, have been noted at Stations 1 to 4. The overall average stage of male gamete development was slightly higher at Station 1 than at Station 4 with the other 2 stations intermediate. The period of time during which motile sperm are found is longer at Stations 1 and 2 than at Stations 3 and 4 (Figures 2 to 5). Variations in the average stage of female gamete development were observed but not at the same stations as for male gametes. The highest overall averages were noted at Stations 2 and 3 and the lowest at Stations 1 and 4.

It is apparent from these data that the propagation of *Mytilus edulis* in Alamitos Bay is dependent upon the presence of mature ova. Some males with mature, motile sperm were observed throughout the year, but mature ova were observed only during the late fall and winter months when water temperatures were at their lowest level (13° to 15° C). The maturation of male gametes does not seem to be affected by the range of water temperatures in Alamitos Bay as it is in British waters (CHIPPERFIELD, 1953); however, the maturation of the ova apparently is influenced by temperature in Alamitos Bay. The presence of motile sperm for a longer period of time than mature ova may be the result of: (1) not all sperm from a mussel are discharged at any one time, (2) additional sperm are produced rapidly and many times a year following a complete spawning, or (3) a combination of these. The shorter period of time in which mature ova are present may be the result of: ova are spawned from one mussel at one time and additional ova mature slowly and are produced only once a year.

The period of settlement of *Mytilus edulis* on boat floats in Alamitos Bay in the late winter to early spring months substantiates these observations of a late fall to winter spawning season. The length of larval life is un-

known for these waters, but CHIPPERFIELD (*op. cit.*) calculated it to be about 4 weeks.

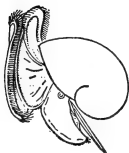
As noted above, there are indications that some ecological variations in the average stage of gamete development occurs in Alamitos Bay. It would be of interest to study this variation in a body of water where the population of mussels is sufficient in the environmental extremes. Secondly, *Mytilus edulis* would be a convenient organism with which to work in order to study the relationship of temperature, as a function of latitude, to the length of the reproductive period.

SUMMARY

1. Gonadal smears of the bay mussel *Mytilus edulis* were made at 4 stations at monthly intervals for 20 months in Alamitos Bay, Long Beach, California, to ascertain whether or not seasonal variation in gamete maturity exists.
2. Some degree of gametogenesis occurred throughout the period of observation. Mature sperm were present in some mussels throughout the year, but mature ova were present only from November through May. The number of indeterminate individuals varied directly with the water temperature.
3. Some slight variations were noted in the average stage of gamete development with both sexes collected from the different stations.

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Two New Cypraeid Species in the Genus *Erronea*

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 46)

ANOTHER COWRIE SPECIES that appears not to have been previously known has been sent to me by Mr. Fernando G. Dayrit of Manila. This very interesting animal was collected at the northern end of Samar Island, eastern Philippines, in the area of San Antonio.

At first inspection the shell reminds one of the east Australian *Erronea* (*Gratiadusta*) *walkeri continens* (IREDALE, 1935). However, many of the shell characters and the dorsal color-layering prove it to be otherwise. The differences are striking, and there seems to be no other alternative than to compare it with another east Australian species, *E. (Adusta) xanthodon* (SOWERBY, 1832), to which it seems most closely related. Because this shell does appear to be new to science I propose to call it

Erronea fernandoi C. N. CATE, spec. nov.

(Plate 46, Figures 1a to 1d)

Holotype: Shell long, narrow, sub-pyriform, heavy; base somewhat convexly swollen, narrowly concave anteriorly; lip narrow; terminals well formed, semi-beaked; margin perceptibly thickened on left side and rounded; right margin thickened, angled, upswept and shouldered; both margins flattened anteriorly, flanged, forming a sharp angle with vertical surface of body whorl; aperture straight, narrow, sides parallel; teeth numerous, very small, fine, slightly longer on columella, — on outer lip

short, blunt, broader, with wider interstices, — in either case only very slightly extending onto base; columella smooth posteriorly, with adaxial edge indistinctly lined with widely spaced, barely visible, larger, rudimentary teeth; columellar teeth pronounced at apical point of long, narrow, shallow fossula, where base teeth are much heavier, and cross the fossula in bold relief; terminal ridge almost straight, abapical left side bifidly grooved into two parts; rear surface of shell umbilicate, with dark-brown to brownish black apex faintly visible within.

Primary shell color light grey, overlaid with a thick mass of irregularly spaced light brown flecks, resulting in an olive green appearance, which is much lighter in some specimens; a central wide dark brown blotch, in some cases a broad band, covering approximately one third of the dorsum (a central dorsal blotch would be an exception to this), extends from margin to margin, becoming lighter as it approaches left side; large dark brown color blotches on either side at base of abapical terminal collar, with loosely scattered large brown spots in both margins, nearly becoming obscure on the base; base, teeth, interstices, and inner surface of terminals white, occasionally very pale beige; columella and upper surface of terminals pale brown.

Measurements: The holotype of *Erronea fernandoi* is 19.0 mm long, 10.4 mm wide, and 8.8 mm high, and shows 22 labial and 18 columellar teeth; the terminal ridges were excluded from the count.

Explanation of Plate 46

Figures 1 a to 1 d: *Erronea fernandoi* C. N. CATE, spec. nov. ($\times 2\frac{1}{2}$)

Figures 2 a, 2 b: *Erronea steineri* C. N. CATE, spec. nov. ($\times 2\frac{1}{2}$)

1 a, 2 a: Dorsal view; 1 b, 2 b: Ventral view; 1 c: Right lateral view; 1 d: Left lateral view of the holotypes.

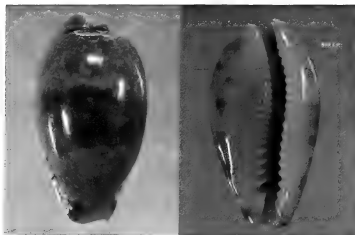


Figure 1 a

Figure 1 b

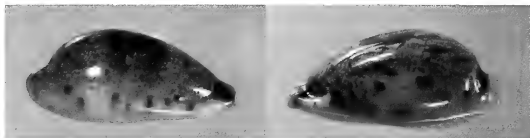


Figure 1 c

Figure 1 d

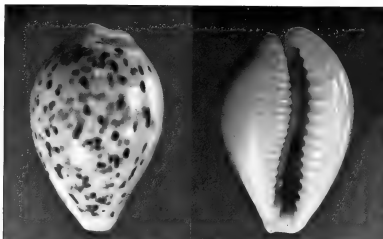


Figure 2 a

Figure 2 b



Type Locality: The animal was alive when collected in approximately 10 feet of water at San Antonio, Samar, Philippines, the type locality for the species. Located in southwestern Samar, on San Pedro Bay (approximately 11° 03' N Latitude; 125° 00' E Longitude), this locality is noted for many other cowrie species.

Type Repository: The holotype will be deposited in the California Academy of Sciences Geology Department Type Collection where it will bear the catalogue number 13158.

I have named this species in honor of Mr. Fernando G. Dayrit, who has contributed many new species to science and thereby has added to our knowledge of the mollusca.

Discussion: The species most closely related to *Erronea fernandoi* appears to be *E. xanthodon* (SOWERBY¹¹, 1832), but *E. fernandoi* differs from the East Australian form in having 2 unusual obliquely transverse ridges on the left anterior ridge; by having shorter, oblique abapical terminal teeth; by having a long, narrow, shallow and heavily denticulate fossula; by the distinctly sharp upper edge of the columella; by the margins becoming pinched and more distinctly flanged anteriorly, which produce deep indentations on either side of the terminal collar; by having a large dark brown dorsal blotch; and by having a white base, white teeth and interstices.

The affinity of these two species to one another is evident. The outstanding differences in the two species are distinctly obvious in the unusual white base (occasionally it may vary to a pale beige), and the large dorsal blotching (a character almost never seen in *Erronea xanthodon*). However, while there might be some justification for considering these two cowrie forms as subspecies because of some similar morphological features, I am provisionally listing this new cypraea as a full species.

Since having completed the work on the supposedly unique specimen of *Erronea fernandoi*, two additional specimens were given to me for identification by Mr. William Old, American Museum of Natural History. I am including them here for comparative purposes. I shall designate the larger of the two shells hypotype 1, and the smaller of them hypotype 2 (the 2 new specimens are not a part of the original type lot from southwestern Samar, but appear to have been collected at Zamboanga City area, Mindanao, a point considerably to the south of the type locality). The data for the 2 shells from southern Mindanao, using the millimeter scale for length,

width, and height, and counting the teeth on lip and columella are as follows:

hypotype 1: (29.5 16.8 13.6 24 21)

hypotype 2: (22.4 13.3 11.0 21 18)

The Zamboanga specimens, as can be seen, are both considerably larger shells; in addition it should be pointed out that the large brown dorsal blotches on these 2 shells appear as large central islands of color, rather than the sweeping transverse band of color shown in the holotype (Plate 46, Figure 1a). In contrast, this dorsal color blotching is almost never, if at any time, seen in the East Australian *Erronea xanthodon*. I wish to thank Dr. Franz A. Schilder for confirming the decision I had made that *E. fernandoi* is, in fact, a new species.

Erronea steineri C. N. CATE, spec. nov.

(Plate 46, Figures 2a, 2b)

Shell of medium size, pyriform, elevated and bulbously inflated, light weight, strong; base narrow, convex; terminals well formed, barely protruding, with openings appearing to be small for the size of the shell, especially abapically; apex umbilicate; sides only slightly thickened, rounded; teeth on outer lip fairly large, broad, interstices shallow; base teeth weakly formed, though distinct, centrally long over base, becoming shorter in front; curving fossula extends half the length of shell, is fairly deep, denticulate, terminating boldly on inner edge of fossula; columella broad, smooth; aperture wide, curving, weakly constricted abapically; shell narrowly, transversely banded with 4 dark lines barely visible through surface, most distinct on left side. Primary shell color pale ivory-white; dorsum loosely, though generously, flecked with light chestnut-brown; sides, terminals, base, teeth, interstices pale ivory-white; columella pale ivory-white spotted with 8 large pale chestnut-brown spots, well separated, arranged in vertical pairs; brownish-black apex barely visible at bottom of umbilical depression.

Measurements: The unique holotype of *Erronea steineri* is 22.6 mm long, 14.5 mm wide, 12.3 mm high, and has 16 labial and 17 columellar teeth; terminal ridges are not included in the count.

Type Locality: This animal was collected alive during April, 1968, in the shallow subtidal waters of Ufa; this small island is a member of the Russell Island Group, situated approximately 30 miles northwest of Guadal-

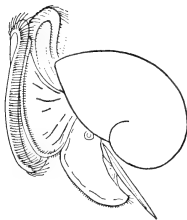
canal in the southeast British Solomons (approximately 9°08' S Latitude; 159°00' W Longitude).

Type Repository: The holotype will be deposited in the California Academy of Sciences Geology Department Type collection, where it will bear the catalogue number 13157.

Discussion: *Erronea steineri* is a fully adult live-collected shell, possessing many of the visible morphological aspects of both *Erronea hungerfordi* (SOWERBY^{III}, 1888) and *E. subviridis* (REEVE, 1845). Possibly the new species fits morphologically somewhere in between the two. However, it seems quite distinct from any other cowrie species.

Erronea steineri differs by having less prominent terminals, a conspicuously different shell shape, longer base teeth, less thickly formed margins and sides, and a different and unusual color design on the dorsal shell surface.

I am naming this new cowrie species in honor of Mr. Franz B. Steiner, Field Associate, Department of Invertebrates, California Academy of Sciences, San Francisco, who first realized this cypraeid might be new to science. I wish to thank Jean Cate for the photographs illustrating both of these new cowrie species, as well as for other assistance in arriving at the conclusions contained in this paper.



Growth Study in *Olivella biplicata* (SOWERBY, 1825)

BY

RUDOLF STOHLER

Department of Zoology, University of California, Berkeley, California 94720

(1 Map; 1 Text figure; 11 Tables)

INTRODUCTION

THE STENOGLLOSS SNAIL, *Olivella biplicata* (SOWERBY, 1825) has a wide range of distribution along the coast of western North America, extending, according to KEEN (1937), from Magdalena Bay to southern British Columbia. Within this range I have collected or observed this species from Estero de Punta Banda in Lower California to Seaside, Oregon and found it always to be very abundant in the proper habitat.

At Duxbury Reef in Bolinas Bay, Marin County, California, where I made regular visits at 2-week intervals for over a year and a half, there are several sand flats measuring, on an estimate, between 2000 (the smallest) and 10000 m² (the largest). An attempt was made to estimate the population of *Olivella* in the latter area. One square meter areas were delimited by strips of stainless steel and the sand was removed to a depth of 4 inches and sifted through a 1 mm mesh screen. From 5 such samples, taken randomly, I arrived at an estimate of 250000 individuals for this particular area. Estimates in other localities along the range of my observations vary from a minimum of 10 to a maximum of 98 individuals per square meter. Chance encounters of 540 or so individuals concentrated in an area of less than 4 square decimeters (i. e., less than half a square foot!) at 3 different localities were, of course, disregarded in these estimates. It is, therefore, justified to call *O. biplicata* a common species.

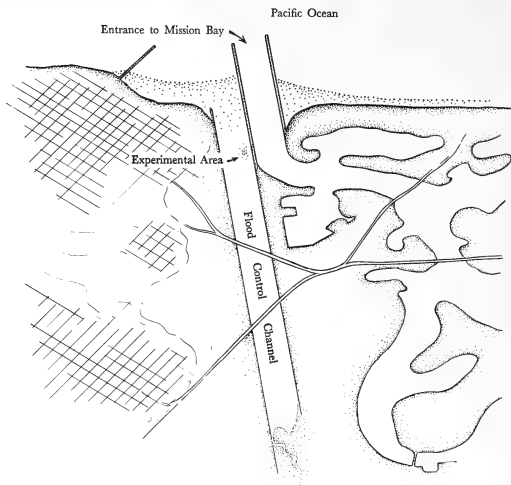
Olivella biplicata seems to thrive equally well in the intertidal sand flats of exposed stretches of the coast and in protected areas of harbors, bays, and esteros. This statement is based on estimates of population densities in various areas, as discussed above.

As *Olivella biplicata* reproduces throughout the year, at least within the area of its occurrence in California (EDWARDS, 1968; STOHLER, 1959/1960; ZELL, 1955) and in Oregon (EDWARDS, *op. cit.*), estimates of longevity based on "year classes" are impossible. At Duxbury Reef I noted that these animals upon the return of the

waves after a low tide travel surprisingly rapidly and far, often several meters in less than half an hour. Under such conditions it appeared hopeless to undertake a long-range growth study in an area facing the open ocean, as the probability of recapturing marked individuals would be practically zero on the basis of pure chance alone. However, when I observed the thriving population of *O. biplicata* in the Flood Control Channel (FCC hereinafter) at San Diego, California (see Sketch Map) a possibility of recovering adequate numbers of marked individuals appeared reasonably certain. Early efforts along this line of endeavor have been detailed in STOHLER, 1962. Not only was this assumption proved correct, but additionally several observations became possible here which could not have been made in the open ocean without grave danger to personnel.

In the FCC there are channels in the sand which at extreme low tide are still covered by several feet of water; no accurate measurements have been made, but by the fact that divers standing at the bottom were covered by about 2 feet of water, an estimate of about 7 to 8 feet depth appeared reasonable. It was reported (STOHLER, 1959/1960) that *Olivella biplicata* remains dormant in the intertidal area during exposure of the habitat at low tide and that, upon first return of waves after the turning of the tide, the animals become very active again. The same behavior is observed even though the sand remains covered by several feet of water in the FCC; thus, the best success in recovering marked specimens was obtained just after slack tide; this held true whether the low tide was early in the morning or late in the evening.

Another observation which seemed surprising to me was that certain individuals were recaptured within a few feet of the spot where they had been dropped on previous occasions. To be sure, there was a certain amount of scattering to be noted; however, it is impossible to state that this scattering is due solely to the active moving of the animals, or that it may be attributable wholly or in part to a passive dislocation by external agents, such as heavy waves or strong currents. It was



Map of the Flood Control Channel in San Diego, California

observed under water that individuals are carried fairly long distances by the currents if the animals become dislodged. Nevertheless, it must be assumed that some active travelling does occur as all captured animals, marked and unmarked alike, were returned after examination in one small area of less than a square meter. These artificially created densities of populations – several thousand individuals per square meter – would probably cause the individuals to seek less densely populated feeding grounds.

The FCC was, however, not without disadvantages. Since it is a flood control channel, at times of extremely heavy winter rains there is a very heavy run-off of fresh water, and though fresh water may tend to form a layer above the sea water it will, nevertheless, tend to kill off many of the animals living in the upper portions of the sand exposed or nearly exposed at low tide. Such extreme-

ly heavy rainfalls do not occur often in the San Diego area and during the term of our observations there only two such events took place, both times with – for the purposes of this study – catastrophic results.

Another disadvantage of the FCC for the study is its accessibility to the pleasure fishermen and their families. The children pick up the rather attractive shells of *Olivella biplicata* and carry them away. However, the worst case was that of a "shell jewelry" collector who scooped up many thousands of *Olivella* animals exactly in the experimental area. These untoward occurrences are reflected in the tables, to be discussed below, by the small numbers of animals gathered on various occasions.

The entire study was carried out over a period of 9 years, from July 27, 1959 to July 13, 1968. The area was visited every 3 months and strenuous efforts were made to recover as many marked individuals as possible. This

required the participation of several to many individuals and it is a great pleasure to acknowledge the enthusiastic participation of many persons; it would hardly be fair to single out any individual for special thanks, except perhaps a few who participated at every "*Olivella* Dive"; among these are Mrs. Fay Wolfson, Mr. and Mrs. R. Dilworth and, later, practically all the members of the San Diego Shell Club and at one time or another, members of various SCUBA diving clubs from the San Diego region. Without this help, it would have been impossible to carry out this study since one individual could not possibly hope to collect, even under the best conditions, the number of individuals obtained on the different occasions. To all these persons go my sincere thanks.

MATERIAL AND METHODS

The species used for the investigation reported here is *Olivella biplicata* (SOWERBY, 1825). As described earlier (STOHLER, 1962), the animals were collected first at

Solana Beach, a few miles north of San Diego; later, the collections were made at Shelter Island in San Diego Harbor by members of the San Diego Shell Club. Until measured, selected and marked, the snails were maintained in large tanks with running sea water in the experimental aquarium of Scripps Institution of Oceanography at La Jolla. The method of measuring and marking was given in an earlier paper (STOHLER, 1962).

Other methods of marking had been tried, as stated in the earlier report, and found unsuitable. Tagging with discs, permitting individual numbering, as described by DARBY (1964) for *Tegula funebris* (A. ADAMS, 1855) was deemed highly desirable from the point of view that this method would be capable of yielding accurate results, but was considered unsatisfactory because the protruding tags would interfere with normal activities of the marked snails and thereby possibly affect growth rate and life span.

To obtain simultaneously data for several stages in the growth series of *Olivella*, the animals in 1961 were di-

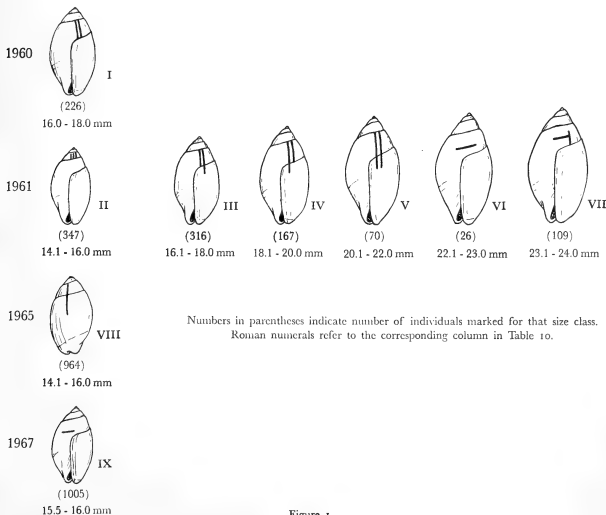


Figure 1

Marks used in different years and for different size classes

vided into different size classes and marked differently (see Figure 1). After the heavy rains of December 1964 this particular series was forcibly terminated. In 1965 I returned to the marking of a single size class, but to offset the predation by sea gulls and removal by human beings I used almost 1000 individuals. When this particular experiment again was terminated by the heavy rains of 1966, I selected for the final attempt in 1967 a much more limited size class, spanning not more than $\frac{1}{2}$ mm, while previously the size classes comprised all individuals within a 2 mm range. This last selection was made possible by the enormous number of specimens collected by members of the San Diego Shell Club. It was possible to select over 1000 individuals in the size range 15.5 to 16.0 mm, with a majority measuring exactly 15.5 mm. Although I did not keep a count of the total number, I think close to 25 000 animals were collected; from these the experimental group was selected. Of course, as always, the unused animals were returned to their original habitat and the marked ones were deposited in the experimental area in the FCC.

Table 1

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1960	XI 5	5	{18.6 }	{20.25}	{19.07}
	XI 6	3	{18.88}	{19.7 }	{19.26}
1961	I 28	7	18.6	20.25	19.14
	IV 22	4	17.7	20.9	19.1
	VII 4	6	17.6	19.7	18.53
	X 14	0			
1962	I 6	2	19.3	20.1	19.7
	IV 14	3	18.5	25.0	20.83
	VII 12	2	19.2	21.0	20.01
	X 6	0			
1963	I 13	1	22.52		
	IV 6	1	20.9		
	VII 21	4	20.18	25.55	23.11
	X 5	0			

starting date: 16 VII 1960

226 individuals marked

starting sizes: 16.0 mm to 18.0 mm

minimum increment 2.18 mm to 4.18 mm

maximum increment 9.55 mm to 7.55 mm

RESULTS

The results are summarized in the 11 Tables that follow.

General explanation for the tables: Because of the range in each size class (2 mm in the case of Tables 1, 2, 3, 4, 5, and 8; 1 mm in that of Tables 6 and 7; and $\frac{1}{2}$ mm in that of Table 8) minimum and maximum increments given at the foot of each Table are cited with these beginning ranges reflected in the end results. In Table 1, separate recovery collections were made on 2 successive days and the results computed separately; these are recorded brackets in { } in the Table, with the total from both days following in the appropriate columns. Because of the possibility of adversely affecting the marked animals by keeping them overnight in an aquarium, no more collections were made on successive days thereafter.

Table 1: Of the 226 individuals marked in 1960 only 4 were recaptured after 3 years. Because of the initial size range of 2.0 mm an accurate measurement of the total increment is impossible. However, it is possible to state that *Olivella biplicata* grew not less than 2.18 mm nor more than 9.55 mm in the 3 years. It is noteworthy, however, that at least one individual had attained almost the final size as much as 1 $\frac{1}{4}$ years earlier.

Table 2

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	13	15.4	19.2	17.77
1962	I 6	3	17.8	19.1	18.46
	IV 14	7	17.4	20.4	18.72
	VII 12	7	17.9	21.7	20.24
	X 6	8	18.8	22.7	20.54
1963	I 13	5	22.8	23.9	23.49
	IV 6	8	19.0	25.2	22.53
	VII 21	10	19.6	26.8	22.64
	X 5	4	21.2	23.6	22.5
1964					
1965					
1966	VII 9	1	24.9		
1967	IV 2	1	27.8		

starting date: 3/4 VII 1961

347 individuals marked

starting sizes: 14.1 mm to 16.0 mm

minimum increment 11.8 mm

maximum increment 13.7 mm

Table 2: Of the 347 individuals marked in 1961, one was recovered as much as 5½ years later and had, by that time, attained almost the maximum size (31.2 mm) reported for *Olivella biplicata* (STOHLER, 1960).

Table 3: This group was of some interest because for almost 2 years no member of this size class was recovered; yet, when at the end of 4 years one specimen was found, it had grown less in this total time than one other specimen had in one year.

Table 3

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	5	17.4	19.8	18.96
1962	I 6	1	20.2		
	IV 14	2	19.9	21.0	20.45
	VII 12	3	21.0	25.8	22.83
	X 6	4	19.7	22.9	21.2
1963	I 13	2	23.1	25.5	24.3
	IV 6	2	23.1	23.3	23.2
	VII 21	5	22.2	24.3	23.42
1964					
1965	VII 24	1	23.6		

starting date: 3/4 VII 1961

316 individuals marked

starting sizes: 16.1 mm to 18.0 mm

maximum increment (any indiv.) 9.7 mm to 7.8 mm

minimum increment (last captured individ.) 5.5 mm

maximum increment (last captured individ.) 7.5 mm

Table 4: Again one individual recovered after 3 years had grown less than one other individual had grown in one year.

Table 5: This group and the next yielded the poorest results. Because of a peculiar mark caused by a slip as the shell was pressed against the marking drill, the individual animal was recognized; unfortunately, an opportunity to obtain exact results was missed in this instance. I did not anticipate the possibility of recapturing exactly the same individual 4 times at various intervals and therefore did not record the individual size of the one where the shell had slipped. Thus, the animal whose measurements are recorded in Table 5 may have been as small as

Table 4

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	3	20.1	20.8	24.43
1962	I 6	2	21.4	22.0	21.7
	IV 14	5	20.7	22.2	21.42
	VII 12	1	23.3		
	X 6	1	24.0		
1963	I 13	5	21.2	24.7	22.44
	IV 6	4	21.5	23.3	22.43
	VII 21	3	23.9	25.8	24.63
	X 5	1	24.6		
1964	VII 5	1	22.3		

starting date: 3/4 VII 1961

167 individuals marked

starting sizes: 18.1 mm to 20.0 mm

minimum increment (last captured individ.) 2.3 mm

maximum increment (last captured individ.) 4.2 mm

maximum increment (any individual) 7.7 mm to 5.8 mm

Table 5

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	1	21.6		
1962	I 6	0			
	IV 14	1	22.1		
	VII 12	0			
	X 6	1	25.8		
1963	I 13	0			
	IV 6	0			
	VII 21	1	25.9		

starting date: 3/4 VII 1961

70 individuals marked

starting sizes: 20.1 mm to 22.0 mm

minimum increment 3.9 mm

maximum increment 5.8 mm

20.1 mm when marked but could not have been more than 21.6 mm. However, it attained almost its maximum size within the first 18 months.

Table 6: Only one individual of 26 originally marked was recovered after 1½ years. In that time it had not grown more than 1½ mm.

Table 6

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	3	22.1	23.7	23.3
1962	I 6	1	23.6		

starting date: 3/4 VII 1961

26 individuals marked

starting sizes: 22.1 mm to 23.0 mm

minimum increment 0.6 mm

maximum increment (any individual) 1.6 mm

maximum increment (last captured individ.) 1.5 mm

Table 7: In this group we again find that one individual attained in one year a greater length than another in 9 more months.

Table 7

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1961	X 14	4	24.1	24.4	24.75
1962	I 6	0			
	IV 14	4	24.2	25.5	24.7
	VII 12	2	24.7	26.6	25.65
	X 6	1	26.3		
1963	I 13	2	25.2	26.3	25.75
	IV 6	1	24.5		

starting date: 3/4 VII 1961

109 individuals marked

starting sizes: 23.1 mm to 24.0 mm

minimum increment 0.5 mm to 1.4 mm

maximum increment 3.5 mm to 2.6 mm

Table 8: This group was subjected to the effects of one extremely heavy rainfall runoff and one fairly heavy one. Yet one individual survived both of these catastrophes. The lone survivor had added in 3 years a maximum of 11.2 mm to its length.

Table 8

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1965	VII 24	10	14.8	19.8	17.4
	X 17	16	15.3	21.4	18.37
1966	I 15	0			
	IV 17	3	16.9	20.6	19.17
	VII 9	4	16.9	19.6	18.23
	X 15	6	18.0	21.6	18.22
1967					
1968	VII 13	1	25.2		

starting date: 10/12 I 1965

964 individuals marked

starting sizes: 14.1 mm to 16.0 mm

minimum increment 9.2 mm

maximum increment 11.2 mm

Table 9: In some respects this was the most disappointing experiment. Of the very large number (1005) of experi-

Table 9

	Date of recapture	Number recaptured	Smallest individual recaptured	Largest individual recaptured	Mean
1967	X 15	2	16.2	17.3	16.75
1968	I 13	0			
	IV 6	13	17.0	19.8	18.45
	VII 13	16	15.6	20.6	18.64

starting date: 11/13 VII 1967

1005 individuals marked

starting sizes: 15.5 mm to 16.0 mm

minimum increment 0.1 mm

maximum increment 5.1 mm to 4.6 mm

Table 10
Minimum and Maximum sizes At Six Months Intervals

	I (226) 14.0-16.0	II (347) 14.1-16.0	III (316) 16.1-18.0	IV (167) 18.1-20.0	V (70) 20.1-22.0	VI (26) 22.1-23.0	VII (109) 23.1-24.0	VIII (964) 14.1-16.0	IX (1005) 15.5-16.0
6 mo	17.8 21.9	17.8 19.1	20.2	21.4 22.0	-	23.6	-	14.8 19.8	-
12 mo	17.6 19.7	17.9 21.7	21.0 25.8	23.3	-	-	24.7 26.6	-	15.6 20.6
18 mo	19.3 20.1	22.8 23.9	23.1 25.5	21.2 24.7	-	-	25.2 26.3	16.9 19.6	-
24 mo	19.2 21.0	19.6 26.8	22.2 24.3	23.9 25.8	25.9	-	-	-	-
30 mo	22.5	-	-	-	-	-	-	-	-
36 mo	20.2 22.6	-	-	22.3	-	-	-	-	-
42 mo	-	-	-	-	-	-	-	25.2	-
48 mo	-	-	23.6	-	-	-	-	-	-
54 mo	-	-	-	-	-	-	-	-	-
60 mo	-	27.8	-	-	-	-	-	-	-

The Roman numerals at the heads of the columns refer to the preceding 9 Tables.

Numbers in parentheses indicate the numbers of individuals marked in each size group.

The third line in the column headings indicates the respective size ranges for each class.

mental animals only very small numbers were recovered on subsequent dives. Still, because of the narrowness of the initial size range, the results seem to me to have some value. One individual could not possibly have grown more than one tenth of one millimeter in a full year, while another could not have grown more than 5.1 mm.

Table 10: I have attempted to summarize the results presented in the first 9 Tables, listing the maxima and minima attained at 6 months intervals. In columns VIII

and IX the heavy line indicates the termination of the study on July 13, 1968; for all other columns the bottom line represents the final date.

In this representation the columns II through VII, including all the size classes of the experiment started in 1961, present an especially interesting picture. Each size class had last representatives (1 or more) at shorter and shorter intervals; this could lead one to assume that in the FCC *Olivella biplicata* dies when it has attained what

Table 11
Size Increases in Pooled Size Classes

	{1537} (14.0-16.0)	{316} (16.1-18.0)	{167} (18.1-20.0)	{70} (20.1-22.0)	{109} (23.1-24.0)
1 yr	17.6-21.7	21.0-25.8	23.3	-	24.7-26.6
2 ys	19.2-26.8	22.2-24.3	23.9-25.8	25.9	-
3 ys	20.2-22.6	-	22.3	-	-
4 ys	-	23.6	-	-	-
5 ys	27.8	-	-	-	-

minimum and maximum increments at yearly intervals (in millimeters)

1 yr	1.6-7.7	3.0-9.7	3.3-5.2	-	0.7-3.5
2 ys	3.2-12.8	4.2-8.2	3.9-7.7	3.9-5.8	-
3 ys	4.2-8.6	-	2.3-4.2	-	-
4 ys	-	5.6-7.5	-	-	-
5 ys	11.8-13.8	-	-	-	-

appears to be its maximum size here, i. e. ca. 26 to 28 mm. Yet on April 22, 1961 an unmarked specimen measuring 29.3 mm was found, indicating that in FCC *Olivella* might attain as large a size as it does elsewhere and that the 26 to 28 mm size is not the absolute maximum. The possible explanation for the disappearance of the "large" specimens from the FCC may have to be sought in the selective collecting by the shell jewelers.

Special mention may be made of the specimen listed in column II. It had survived 5 full years since the marking.

Table 11: This Table was compiled by pooling all results for each of the 5 different size classes used, in an attempt to uncover possible general trends.

DISCUSSION

DARBY (1964) showed that in *Tegula funebralis* from Sunset Bay, Oregon age can be estimated on the basis of growth lines visible on the underside of the body whorl. In the collection of the Department of Zoology, University of California in Berkeley, there is a large series of the same species from many localities in California. Close examination of these specimens reveals the presence of the "small" incremental lines but does not show any of the "larger" lines which DARBY equates to annual growth lines, except in a few exceptionally large specimens from Duxbury Reef. On the other hand, among an almost equally large series of *T. brunnea* (PHILIPPI, 1848) I observed growth lines of a similar nature on a specimen from Tomales Bay, Marin County, California. I hesitate to interpret the presence of the distinct lines in Oregon material and the general absence of them in our California material as a consequence of possibly more rigorous climatic conditions in Oregon. However, DARBY's work did alert me to the possible significance of lines on the shells of *Olivella biplicata*. By close examination of the specimens that I know to have spent more than one year in the FCC I hoped to discover any significant lines. But there is no regularity in the lines discernible. The general shell pattern is almost devoid of macroscopically visible distinct lines and the few very distinct lines that may be observed on an occasional individual either have an irregular course or are so irregularly spaced that it is hard to conceive of them as "annual" growth lines. The irregularly shaped lines would seem to me to be an indication of a repaired lip and the irregularly spaced lines might be indicative of fluctuations in diet. It cannot be denied, of course, that the growth lines could give a clue to the age of the individual. Unfortunately, our overall

knowledge of the biology of *O. biplicata* at present is insufficient to answer this question.

It seems clear from a study of the various Tables that different individuals of *Olivella biplicata* in the FCC grow at different rates. The greatest increase in size in one year is a possible 9.7 mm (from 16.1 to 25.8 mm), while the smallest is a possible 0.1 mm (or, conceivably, 0.0 mm). It would be interesting to know if the differences in growth rates are due to the sex of the individuals concerned. No attempt had been made to determine the sex of the individuals to be marked as this would have required too much time. Dr. D. C. Edwards was kind enough on the occasion of one of the "*Olivella* dives" to show me his method of ascertaining the sex of an individual; but even with his considerable experience it took an average of 10 minutes per specimen.

The most interesting specimen of the entire series is the one originally marked in July 1961 and recovered in April 1967. In the intervening 5 years and 9 months this animal almost doubled in size. Another specimen of almost equal interest is the one included in Table 9, for which a possible increment of 0.1 mm in one full year was reported.

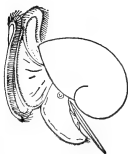
EDWARDS (1968) reports that *Olivella biplicata* matures sexually at about the time the shell attains a length of 16 mm. It would seem then, if this holds true for *O. biplicata* in the San Diego region, that I picked out, with one exception, sexually mature individuals for marking. The consideration for picking the particular sizes was, however, one of convenience in handling and marking. The only exception was the group reported in Table 2. In this case 347 individuals (perhaps) not yet sexually mature were marked; yet within 3 months they had apparently attained a size at which sexual maturity may be presumed. It may appear reasonable to allow a lapse of 2 or possibly 3 years, at the most, for *O. biplicata* to arrive at a sexually mature stage from the veliger stage. But this relatively narrow limit need not really apply when the fact that one individual did not grow more than 0.1 mm in one year is taken into account. It then becomes possible to assume with some degree of justification that the sexually mature stage is not reached before 4, 5, or more years after metamorphosis. When this figure is added to the actually observed time in the one specimen, i. e. $5\frac{3}{4}$ years, an estimate of a total life span, under ordinary conditions, of 8 to 12 years would not appear exaggerated; and under exceptionally favorable conditions perhaps an even longer life span may be expected. This does not appear exorbitant in the light of the estimates of 30 years, more or less, for *Tegula funebralis* made by DARBY (1964).

ACKNOWLEDGMENTS

In addition to the many individuals who have contributed numerous hours in swimming, diving, or otherwise collecting the experimental animals, I owe gratitude to Dr. E. W. Fager who repeatedly made all the facilities of his laboratory available to me for measuring and marking of the shells as well as for maintaining the animals prior to, during and immediately after the marking procedure. The Department of Zoology, University of California, Berkeley, supported the study throughout the several years. Dr. Cadet Hand critically read the manuscript and Mrs. Emily Reid drew the map and the text figure accompanying this paper.

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Distribution of Organic Bromine Compounds in *Aplysia californica* COOPER, 1863

BY

LINDSAY R. WINKLER

College of the Desert, Palm Desert, California 92260

(1 Text figure)

INTRODUCTION

THE EXISTENCE of organic bromine compounds in the lipids of *Aplysia kurodai* BABA, 1937 was first noted during routine studies of marine organisms by TANAKA & TOYAMA (1959). This report led indirectly to the present exploratory study to determine the presence and distribution of bromine-containing organic compounds in the California species, *Aplysia californica* COOPER, 1863.

The work of TANAKA & TOYAMA was introduced to the non-Japanese speaking world by an article on the chemical structure of 2 of the compounds by YAMAMURA & HIRATA (1963). In the first sentence of this latter report the authors state "... but it is our experience that the kind and content of bromo-compounds in *Aplysia kurodai* depends on when and where they were gathered." Since bromo-synthesis is rare in animal metabolism the origin and function of such compounds might be of interest.

As a sequel to this and other papers (WINKLER, 1959 and 1961; WINKLER & DAWSON, 1963) an unsuccessful attempt to locate a biological precursor for these bromine-containing organic compounds in the sea weed *Placodium pacificum* (KYLIN) was reported by DARLING & COSGROVE (1966).

Search of the recent botanical literature revealed articles by a number of authors who reported the presence of organic bromine compounds in a number of species of the red algae. The most recent paper is that of CRAIGIE & GRUENIG (1967), which, together with one by HODGKIN, CRAIGIE, & MCINNES (1966) has bibliographic references to most extant algal papers on the subject. Among the red algae containing bromine organic compounds reported by these authors were listed members of the genus *Laurencia*, previously noted as the major dietary item of some specimens of *Aplysia californica* (WINKLER & DAWSON, 1963).

The previously mentioned paper by YAMAMURA & HIRATA employed the term 'aplysin' in several combinations to denote the bromine-containing lipids of *Aplysia kurodai*. This term, however, had previously been employed to refer to a different, water-soluble toxin found in the digestive gland of *A. californica* (WINKLER, 1961 and 1962). As a result of this duplication of terminology, the term 'organo-bromines' is used in the present paper to avoid confusion.

MATERIALS AND METHODS

The previous Japanese papers reported only on extracts made from entire, dried animals. However, previous exploratory work by the present writer has indicated that the digestive gland was a main locus of lipids in *Aplysia*. Preliminary studies of digestive gland lipids made on celite columns led to the isolation of apolar fractions giving the Beilstein test for halogens. With this assurance of halogen content the determination of relative content of bromine in the various organs was begun using a semi-quantitative paper chromatographic technique adapted for the purpose.

Animals were collected at La Jolla and Doheny Beach, California. Specimens were killed and dissected in the laboratory under hypothermia and were usually divided into the following parts: digestive gland, digestive tract (including oral capsule), kidney, glandular mantle margin, opaline gland, and the foot including total body wall and dermis. Each organ was minced finely with scissors and placed in the thimble of a flask-type lipid extractor and after thorough extraction with acetone the residue was removed, dried, and weighed. After the acetone had been removed from the extract in a current of air, the extract was cleansed of hydrophilic residues, after which it too was weighed and the resultant 2 weights for each or-

gan were added together to give the total dry weight. The extract was then subjected to sodium fusion after which the sodium salts produced were taken up in water, filtered, and reduced to a quantity equivalent to the gram weight of the extracted material, or multiples of that weight if the amount was too small for convenient dilution or too much NaOH was present as a result of excess sodium being used during the sodium fusion.

Chromatograms made of $6\frac{1}{2} \times 8$ inch sheets of Whatman No. 1 filter paper were spotted along a line drawn $\frac{1}{2}$ inch from one of the long edges of the paper with 0.005 ml aliquots of the solution resultant from the sodium fusions. The papers were then formed into cylinders, stapled, and stood in self-supporting position in petri dishes containing the developing solvent. Each was then covered with a gallon-capacity mayonnaise jar during the development period. The developer giving best separation between bromine and chlorine was pyridine and water (90:10). After drying on an histological slide warmer the spots on the chromatograms were made visible by one of 2 methods. The first method involved a silver nitrate spray followed by a 20 minute exposure to fluorescent room lighting. The removal of excess silver nitrate was accomplished by a wash in a weak nitric acid solution and a water rinse. The alternate method involved the use of a spray modified from FEIGL (1958) made up of equal parts of glacial acetic acid, 30% hydrogen peroxide and 5% uramine (sodium fluorescein). After spraying, the chromatograms were placed on the slide warmer set at maximum temperature of 65°C and dried. The bright red color of eosin was formed wherever bromine was present. After thorough airing, such chromatograms were made "permanent" by spraying several times with 'Krylon' plastic spray. These chromatograms are still bright after 9 months. While this method was very specific for bromine, care was required in order to prevent running of the water-soluble eosin dye. It was consequently somewhat less accurate for quantitative estimation than the less specific silver nitrate method which depended entirely upon R_f value for the final identification of the spots.

In order to obtain the degree of quantitation required each chromatogram was dried and the limits of the spots were outlined with heavy pencil lines. The sheet was then imprinted with a rubber stamp having $\frac{1}{4}$ inch quadrangular rulings. The number of squares counted within each spot outline provided a close estimate of the relative area of each spot.

A standard curve was prepared by spotting chromatograms with 0.005 ml of standard dilutions of sodium

bromide, using 4 spots for each dilution. The areas of the 4 spots were averaged and the resulting figures were plotted against quantity of bromine (not NaBr) actually present. The resulting curve became the standard from which quantitative estimates of the unknown spots were determined. Experimental results were read from this curve in grams of bromine in a 100 gram sample.

EXPERIMENTAL RESULTS

Table 1 summarizes the amounts of bromine found in the various organs of a single small specimen taken from La Jolla, California, in February 1966. Figure 1 illustrates

Table 1

Sample Analysis of Bromine Distribution
by the Silver Nitrate Method.

Results represent average values on five chromatographic determinations for each tissue. Averages of four determinations for each organ using the uramine/eosin method gave similar results but the variability between runs was greater.

Organ	Dry weight	Weight of Extract	Gms bromine per 100 gms	Mgm bromine in organ
Digestive gland	4.89	1.64	11.6	12.8
Body wall and dermis	6.65	2.74	0.2	5.48
Anterior digestive tract	1.12	0.20	Neg.	
Mantle margin	0.18	0.13	Neg.	
Opaline gland	0.74	0.13	Neg.	
Kidney	0.32	0.08	0.45	0.36
Total dry weight	13.9 gm	4.92 gm		
Dermis ¹	0.114 gm	0.02 gm	Trace	
Blood ¹	6 ml		Trace	

¹ Results from different animals

the percentage of the total bromine found in each organ in which it was demonstrable as well as the lipid distribution in those organs. Other specimens taken on the same collection trip and on subsequent trips to Doheny Beach, California, indicated similar levels of bromine. The levels given for blood and dermis represent runs on blood and on skin scrapings from other individuals. Amounts of extract from these samples were insufficient, however, for successful quantitation.

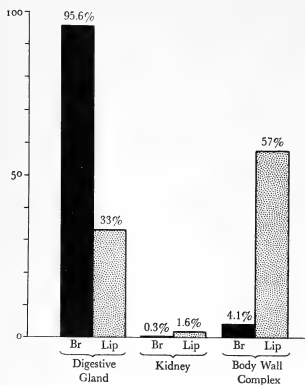


Figure 1

Graphic representation of the percentage of the total bromine-organic compounds (Br) and lipids (Lip) in each organ in which measurable amounts were found. Though the total quantity of lipids was considerably greater in the body wall complex the organo-bromides were found in relatively small quantities compared with the reverse situation in the digestive gland.

DISCUSSION AND CONCLUSION

While bromine was clearly identified by rf value when using the silver nitrate method, the specific reaction of bromine with uramine to form the red dye eosin was a further proof of its identity. The latter reaction appeared quite spectacular against the yellow background of uramine (sodium fluorescein) and even more pronounced when viewed under long-wave ultraviolet light. Since no color reaction was produced with chlorides when this method was used, it was possible to use the less odoriferous ethanol:water (diluted 90:10) as a developer. This latter developer produced a nicer, rounder spot but this was too close to the chloride spot for use when silver nitrate (which was equally good as a chloride revealer) was used for visualization. The uramine/eosin method

was less satisfactory for quantitative work, however, due to running of the soluble eosin produced as opposed to the highly stable spot size resulting from the use of the silver nitrate precipitation.

The results of this preliminary study indicate that the digestive gland is the principal site of organic bromine compounds in the sea hare and that these materials are probably excreted by the kidney and perhaps also by the skin which has previously been suggested as an excretory organ (MacMunn, 1899; Winkler, 1959). These substances may very well be transferred to the foot muscle by way of the blood to become one of the predation-deterrents employed by this mollusk which lacks an external shell. Furthermore, it may be inferred that the brominated organic compounds are probably obtained from the environment rather than being the result of synthesis within the animal. The reports of various red algae containing amounts of brominated organic compounds and the fact that *Aplysia californica* is known to include at least one genus of organo-bromine producing algae in its diet (Winkler & Dawson, 1963) along with the concentration of bromo-organic compounds in the digestive gland, makes the former hypothesis seem more plausible, especially in view of the original statement from Yamamura & Hirata (1963) quoted in the introduction to this paper. On the other hand, its concentration in the digestive gland which is recognized as the normal site of great numbers of enzymatic reactions may indicate that it is there bromated as one of the various, little-understood, detoxification processes.

The absence of the bromine compounds from the opaline gland and the mantle margin would seem to exclude the organo-bromine compounds from a part in these particular predation-deterrent systems. However, their presence in the body wall and skin may indicate that they may function to make *Aplysia* repulsive to potential predators.

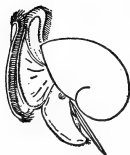
The number of specimens used in this study is admittedly small but is justified by the fact that the information obtainable by this method involving the destruction of the total acetone-extractable lipids is necessarily limited to what we here report - the distribution of the organic bromine fractions within the animal. Further study into the ultimate origin of the brominated compounds and their variation from animal to animal requires the fractionation and identification of the apolar lipids and the determination of the relative quantities of the different bromine containing fractions. Such studies, using more sophisticated equipment and methods, are now in the planning and development stages.

SUMMARY

Organs and organ systems of specimens of *Aplysia californica* COOPER, 1863 were dissected out and extracts were made with acetone. The residues after removal of the acetone were subjected to sodium fusion. The resultant sodium salt was then taken up in water and semi-quantitatively estimated by paper chromatography. Results indicated over 90% of the bromine-containing organic compounds were to be found in the digestive gland and of the remainder more than $\frac{3}{4}$ were found in the foot, body wall and skin complex. Less than 0.3% were found in the kidney. Trace amounts, unmeasurable by the methods used, were found in the blood or hemolymph.

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Quantitative Relationships Between Gill Number, Respiratory Surface, and Cavity Shape in Chitons

BY

KAY M. JOHNSON

(6 Text figures)

INTRODUCTION

CHITONS HAVE A NUMBER of characteristics which suggest that they are a very primitive group of mollusks: an ovoid shape, a broad, flat foot, shells of only two layers – the tegmentum and the articulamentum –, a microphagous, herbivorous mode of feeding, a non-ganglionated nervous system, and a trochophore larva which metamorphoses directly into the adult form. Yet, with all of these primitive characteristics they are not termed an "ancestral mollusk" type. That is largely because of the many gills found in the grooves along the sides of the foot.

YONGE (1939, 1947) describes an "ancestral mollusk" with a posterior mantle cavity with only 2 gills. He believes that the chitons evolved from this ancestor due to a flattening of the animal with an extension of the pallial cavity in grooves alongside of the body. The gills were seemingly forced into multiplying in number and shortening so as to fit into the grooves.

Until recently YONGE's hypothesis was not challenged. With the discovery of *Neopilina galathea* LEMCHE, 1957, a doubt as to the complete validity of YONGE's hypothesis was raised. *Neopilina* was obviously a very primitive mollusk with its ovoid shell, flat foot, and radula. But the most astonishing fact was that it had a series of gills along the side of the foot. To LEMCHE (1957) this was enough to prove that multiplicity of gills was the primitive condition of the molluscan pallial cavity and also enhanced the idea that mollusks had a segmented ancestor. So, from LEMCHE's hypothesis it could be concluded that the gills in chitons are arrayed like the primitive condition and that the number of gills in other groups of mollusks is a reduction.

Only HUNTER & BROWN (1965) have tried studying the gills in chitons in an attempt to show with data just which theory might be reasonable. HUNTER & BROWN studied only the relationship between the weight-length

and the number of gills. Their results showed what they considered too great an asymmetry between the number of gills on each side of animals of equal weight-length for there to be any basis for the idea that chitons are related to a segmented ancestor. And, therefore, the condition of the gills was not even possibly like the primitive state. In other words, they decided that the gills were a secondary replication of structures of the 'ancestral mollusk' as YONGE had hypothesized it.

HUNTER & BROWN may have been correct in concluding that the asymmetry in gill numbers may show a lack of segmentation. But that does not necessarily mean that a multiplicity of gills was not a primitive condition of the mollusks. There are 3 groups which are very primitive mollusks and do have numerous gills – *Neopilina*, *Nautilus*, and the chitons. So, why could not the primitive condition have been a "mantle cavity as a groove bounded by the mantle edge and surrounding the head-foot rather than a posterior cavity"? (FRETTER & GRAHAM, 1962).

HUNTER & BROWN used only 2 species, *Chaetopleura apiculata* (SAY, 1834) and *Lepidochitona cinereus* (LINNAEUS, 1767). And they only counted the number of gills. I have sought to further clarify that picture of the chiton gill cavity by making additional measurements.

MATERIALS AND METHODS

Various measurements of a chiton's gill cavity assist in portraying the gills in relation to the whole animal: (1) the length of the animal along the foot; (2) lengths of the gill series on both sides; and (3) the length of the most posterior gill itself. Also, I counted the number of gills on both sides of the animal. And by likening the effective gill surface (that which water must pass through during respiration) to a triangle I could compute that surface area by using the length of the last gill and the

length of the gill series in the formula: $\frac{1}{2}bh = \text{area of a triangle}$.

These various measurements can be used for a description of the gill cavities of a group of chitons with a wide range of types, sizes, and shapes. I used chitons from 2 suborders and 4 families of different adult lengths and shapes, and of a range of sizes within each species. The species I used are further described below:

Acanthochitonina

ACANTHOCHITONIDAE

1. *Acanthochitona exquisita* PILSBRY, 1893, is a small (1.1 to 3.3 cm) oblong chiton.

Lepidopleurina

ISCHNOCHITONIDAE

1. *Stenoplax (Stenoradsia) magdalenensis* (HINDS, 1844) is a long (2.1 to 9.0 cm), rather narrow chiton.
2. *Tonicella lineata* (WOOD, 1815) is a small chiton (1.8 to 4.4 cm). Its general shape is a gently rounded oblong.

MOPALIDAE

1. *Mopalia muscosa* (GOULD, 1846) is a large (1.1 to 8.1 cm) oval chiton.
2. *Placiphorella velata* DALL, 1879 is a small (0.9 to 2.5 cm) broad, oval, flattened chiton.

CHITONIDAE

1. *Chiton sulcatus* WOOD, 1815 is a large (0.5 to 7.5 cm) chiton which is fairly broad and oval.

All of the specimens were preserved in the collection at the Department of Invertebrate Zoology, California Academy of Sciences, San Francisco. So, I tried to look at a range in sizes of each species of chiton that had come from one collecting area. In that way I could possibly be working on a growth series of a species. Therefore, I chose the following lots:

100 *Acanthochitona exquisita* from Puerto Refugio, Angel de la Guarda Island, Gulf of California; 25 *Stenoplax magdalenensis* from Punta Abreojos, Baja California; 92 *Tonicella lineata* from False Bay, San Juan Island, Puget Sound, Washington; 20 *Placiphorella velata* from Cedros Island, Mexico; 40 *Chiton sulcatus* from near and in Academy Bay, Santa Cruz Island, Galápagos Islands.

Mopalia muscosa was the exception. The Academy did not have a large number of animals from any one place. Therefore I took groups which had been collected along the range of this species. Thus, 17 *M. muscosa* were from

False Bay, Washington; 8 from near San Simeon, California; and 10 from one mile north of Camalu Arroyo near Guerrero, Baja California.

RESULTS

Just as HUNTER & BROWN (1965) showed in *Chaetopleura* and *Lepidochitona*, there is an asymmetry of the right and left sides in the chitons studied. It is evident when one compares the average number of gills per side with the length of an animal, that the right and left sides are not similar. Growth seems to be random. This is easily seen by comparing the gill numbers on either side of *Tonicella lineata* in Figures 1 and 2. Thus, it appears that HUNTER & BROWN's work is correct.

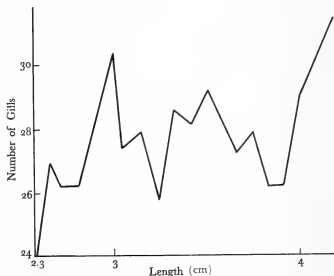


Figure 1

Graph showing the number of gills found on the right side of *Tonicella lineata* of different lengths.

But much more is evident from my data, as may be seen in Figure 3. Those chitons which eventually reach a "large" adult size (8 to 9 cm) have more gills than do those which attain only a "small" adult size (1 to 5 cm). The difference is quite obvious when one compares animals of the same sizes, between 0.5 and 5.0 cm, but of different adult sizes. Thus, some may have adult stages larger than 5 cm and some may not. The "large" chitons are from at least 2 species and 2 different families, yet

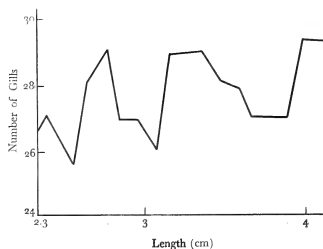


Figure 2

Graph showing the number of gills on the left side of *Tonicella lineata*. A comparison with Figure 1 demonstrates the lack of symmetry between the two sides.

they possess on the average from 4 to 10 more gills per side than do the "small" chitons (which include even representatives of 2 different suborders). Thus, there is

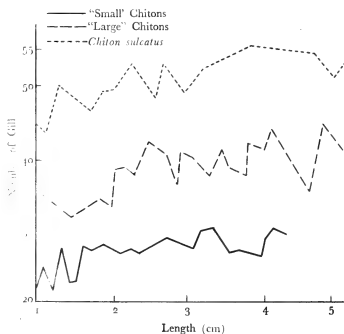


Figure 3

"Large" chitons have more gills than "small" chitons at all lengths

some major difference between "large" and "small" chiton growth.

Chitons of different adult size have the same effective gill surface per unit length. This is found by comparing the gill cavity area with the length as in Figure 4.

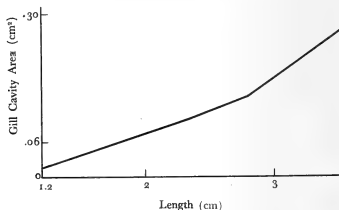


Figure 4

Both "large" and "small" chitons have equal gill surface area per unit length

The difference between "large" and "small" chitons is found when one compares the gill series lengths with the body lengths, and the length of the last gill with the length of the gill series. It appears that the length of the gill series of the "large" chitons are somewhat longer than in the "small" chitons, even when both groups are of the same lengths (Figure 5). And the "small" chitons

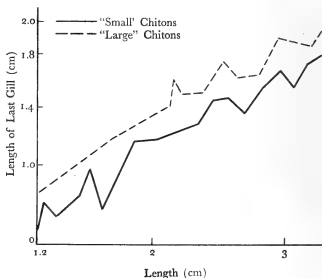


Figure 5

"Large" chitons have longer gill series than "small" chitons

achieve equal gill cavity area by lengthening their gills more than the "large" chitons do (Figure 6). Thus, the most posterior gill of the "small" chitons are longer than

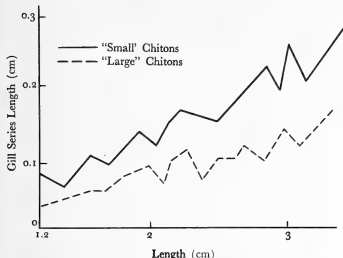


Figure 6

"Small" chitons have longer gills than "large" chitons

the last gill of "large" chitons of equal length. In other words, the "small" chitons have shorter, wider gill cavities than do the "large" chitons.

DISCUSSION

HUNTER & BROWN (1965) may be correct regarding the non-segmented nature of an "ancestral mollusk" type. In fact, my results seem only to support that part of their arguments. The right and left gills of chitons are never completely equal in number.

Deciding that the "ancestral mollusk" was not segmented does not necessarily support YONGE's hypothesis of a two-gilled ancestor. The additional information I have supplied about the chiton gill cavity adds a new perspective to the problem. If the many gills in chitons are due to a forced multiplication of them due to the chitons' being flattened over evolutionary history, why do "large" and "small" chitons differ? If each type, "large" and "small", was achieved separately, why do such similar animals, as those found in the same family, have differently shaped gill cavities? Thus, it seems that YONGE's hypothesis fails to account for these differences in gill cavity shapes.

A simple and more adequate explanation would be that the multiplicity of gills as seen in *Neopilina* or the chitons may be like the primitive condition of the molluscan gills. It seems much more plausible that the two trends seen in the "large" and "small" chiton gill cavities were present in the "ancestral mollusk" and have been maintained by the chitons, than that they were the result of a couple of stages of flattening of the animals. Thus, the two gills found in gastropods and lamellibranchs and the four gills in some cephalopods are most probably the product of a reduction in number of gills with an enlargement of the posterior part of the gill cavity. This reduction in the number of gills would, of course, obliterate the pattern of "small" and "large" animal gill areas. Therefore, it appears that the chitons have maintained a condition found in the "ancestral mollusk" type, although more gills may have been added, since the chitons have so many more gills than does the more primitive *Neopilina*.

SUMMARY

Chitons of "large" adult size have more gills present on both sides of the animal at all sizes than do the "small" adult-size chitons. The difference in number does not affect the effective gill surface per unit length. The effects of the difference in number on the area of gills are equalized in the "small" chitons by possession of longer gills. Therefore, the "large" chitons have long narrow gill cavities, while the "small" chitons have short wide gill cavities.

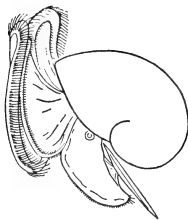
These two trends in the chitons do not seem to be adequately explained by YONGE's hypothesis as to the origin of the multiplicity of gills in chitons. A more adequate explanation is that the trends were present in some "ancestral mollusk" type and have been maintained in the chitons and in *Neopilina*. All other mollusks have, therefore, modified this primitive gill cavity.

ACKNOWLEDGMENTS

I would like to thank Dr. Michael T. Ghiselin of the Department of Zoology, University of California, Berkeley, for his kind assistance throughout this project and for criticizing the manuscript. Also, I would like to thank Mr. Allyn G. Smith of the California Academy of Sciences for his help and for allowing me to use the collection of preserved chitons in his care.

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Recognition of an Eastern Pacific *Macoma* in the Coralline Crag of England and its Biogeographic Significance

BY

EUGENE V. COAN

Department of Biological Sciences, Stanford University
Stanford, California 94305

EVIDENCE HAS BEEN ACCUMULATING over the last few years that Bering Strait was open during the late Miocene, closed through most of the Pliocene, then open and closed several times from the late Pliocene through the Pleistocene. These submergences allowed the exchange of marine life, chiefly from the Pacific to the Atlantic Oceans (MACNEIL, 1965; HOPKINS, 1967).

Pacific elements in the Coralline Crag of England, of Astian (Pliocene) age (BADEN-POWELL, 1960), may represent either late arrivals from the late Miocene submergence (Hopkins, personal communication) or early arrivals from the late Pliocene submergence (Zullo, personal communication). The larger influx (in terms of the number of species) of Pacific elements present in the Red Crag (Pleistocene) of England and similar deposits on the mainland of Europe and in Iceland may represent either an event of submergence in the Bering Strait area or similar tectonic events in the Canadian archipelago (HOPKINS, 1967).

In connection with a revision of the Eastern Pacific Tellinacea, I can now report further evidence concerning the trans-Arctic migrations of mollusks. The boreal species of the genus *Macoma*, with a geological record from the Eocene to the Recent in the Eastern Pacific (KEEN & BENTSON, 1944), have recently been discussed as not having reached the Atlantic Ocean until the Pleistocene influx (DURHAM & MACNEIL in HOPKINS, 1967). I find that *M. obliqua* (SOWERBY, 1817)¹, reported from the Coralline Crag of England (WOOD, 1848, 1874; British Museum [Natural History], 1963) and from the correlative, Scandisian strata in Belgium (GLIBERT, 1958a, b), is conspecific with a Recent West American boreal species, commonly identified with *M. incongrua* (VON MARTENS, 1865)².

Macoma lyelli DALL, 1894, described from the late Miocene or early Pliocene of Marthas Vineyard, Massachusetts (also DALL, 1900b), and *M. cookei* GARDNER, 1943, described from the Upper Miocene of Virginia seem to be closely related.

As Recent and fossil Eastern Pacific specimens of *Macoma obliqua* differ significantly from Recent material from Japan, type locality of *M. incongrua*, the Western Pacific form should be regarded as a distinct subspecies or species. *Macoma obliqua* has become extinct in the North Atlantic since the Pleistocene.

¹ *Tellina obliqua* J. SOWERBY, 1817, non WOOD, 1815. The International Commission on Zoological Nomenclature has been petitioned to conserve the name of this well-known Cenozoic fossil which has only recently been discovered to be a junior homonym of an unimportant junior subjective synonym. Type specimens of the Sowerby species are in the British Museum (Natural History), and Stanford University now has specimens from the Red Crag which have been compared with this type material.

² *Tellina incongrua* VON MARTENS, 1865. A potential lectotype, measuring 25.4 mm in length, is in the Zool. Mus., Humboldt Univ., Berlin, no. 7624. Synonyms appear to be *Tellina nasuta truncata* MIDDENDORFF, 1851, non LINNAEUS, 1767, and *T. nasuta brevior* SCHRENCK, 1867. *Macoma frigida* (HANLEY, 1844), described from Kamchatka, seems to be a closely-related, but distinct species.

DALL (1900a) suggested that *Tellina rotundata* SOWERBY, 1867, might be a synonym of *Macoma incongrua*. The type specimen in the BM(NH) proves to be *M. balthica* (LINNAEUS, 1758). He also suggested that *M. californiensis* BERTIN, 1878, was a synonym. Photographs of the type specimens of the latter, kindly provided by l'Ecole des Mines, Paris, prove these to be *Macalia bruguieri* (HANLEY, 1844), mislabeled as to locality, for the species is Asian.

The synonymy of *Macoma obliqua* and the West American *M. incongrua* of authors, foreshadowed by the association of the two names in the Pleistocene of Iceland (EINARSSON, HOPKINS, & DOEL in HOPKINS, 1967), suggests that migrations from the Pacific to the Atlantic during the first Cenozoic submergence of Bering Strait in the late Miocene may have been more extensive in terms of the number of species involved than previously thought (as listed by DURHAM & MACNEIL in HOPKINS, 1967). West American paleontologists and marine molluscan systematists will have to take into account this exchange and the resulting nomenclatural involvements with European and Atlantic fossil species.

I would also suggest that the isolation created by the Pliocene land bridge subsequent to the late Miocene sea passage may partially explain the presence of so many boreal species of some genera, such as *Macoma*, in the North Pacific Basin. For instance, *M. middendorffi* DALL, 1884, a related Bering Sea species, with published records in the Miocene, Pliocene, and Pleistocene of the North Pacific, may represent the population which remained in the Pacific Ocean when *M. obliqua* traveled to and became isolated in the Atlantic-Arctic in the Pliocene.

A preliminary survey of literature indicates that another, now extinct species of boreal *Macoma* may have reached the Atlantic as early as the European Anversian (Miocene). Taxa that ought to be compared with one another in order to prove this are *M. albaria* (CONRAD, 1849), *M. virginiana* (CONRAD, 1866) (and its subspecies), and *M. elliptica* (BROCCHI, 1814) of GLIBERT (1958a, 1958b) and others.

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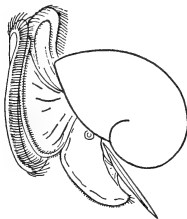
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NOTES & NEWS

A Color Variation of *Aldisa sanguinea*

BY

RICHARD A. ROLLER

1127 Seaward Street, San Luis Obispo, California 93401

(1 Text figure)

COLLECTION AND OBSERVATION of a fairly large number of specimens of the nudibranch *Aldisa sanguinea* (COOPER, 1862) over a 2-year period in San Luis Obispo County, California, have shown that this species commonly has varying amounts of yellow pigment on the dorsal surface. This pigment tends to be arranged in repeated patterns, frequently in the shape of a "T".

Color descriptions of *Aldisa sanguinea* given in the literature by BABA (1949), COOPER (1862), MacFARLAND (1905, 1906, 1966), MARCUS (1961), and O'DONOGHUE (1927) indicate a body color of red, in varying shades, accompanied generally by two black spots on the median line of the dorsum. No mention is made in the literature of any yellow pigment or distinctive yellow pattern.

PRUVOT-FOL (1954, p. 268; fig. 106) pictures a "T"-shaped marking for *A. banyulensis* PRUVOT-FOL, 1951, a red species with whitish stripes. BABA (1949, plt. 25, fig. 94) shows a figure of *Halgerda rubicunda* BABA, 1949 with a similar "T"-shaped marking, except that the "T" points in an anterior direction, rather than a posterior one. The animal is described (*op. cit.* p. 135) as "General body colour orange-red, a short longitudinal band of dull yellow medianly between the rhinophores, and there is another, but transverse, band of the same colour a short distance in front of the branchiae."

To date 27 specimens of *Aldisa sanguinea* (from 11 to 35 mm in length) have been collected or observed alive by the author. Of these animals, 17 had an obvious chrome-yellow "T"-shaped marking on the posterior half of the dorsum. This marking is made up of a dense series of fine yellow dots forming an irregular band across the dorsum, just ahead of the posterior black spot. This yellow pigment disappears completely from the median area of the dorsum. A similar yellow band extends from the branchial area, posteriorly along the median line to the mantle edge (Figure 1).

Of the 27 animals observed, all but 2 exhibited a transverse yellow band across the dorsum, and only one

animal had no observable yellow pigment. Many of the animals were heavily marked with yellow pigment, scattered in varying amounts, over the anterior or posterior regions of the dorsum, or both, the branchial plumes, and the anal area inside of the branchial plumes.

Continued collection of specimens with variations from the usually reported color tends to make this color variety the expected one for this area. Baba (personal communication) states that he has not seen a single "T"-shaped marking in Japanese specimens of *Aldisa sanguinea*.

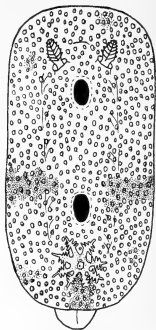


Figure 1

Aldisa sanguinea (COOPER, 1862)

Stippling indicates yellow pigment

nea. No collectors that I have contacted have seen this color variation anywhere except in San Luis Obispo County; however, a color slide by Mr. Robert Ames of Oakland, California, shows 2 specimens with transverse yellow bands. It is hoped that anyone collecting specimens of *A. sanguinea* will look for similar markings and pigmentation; and I would appreciate any information on the color pattern of this species.

I acknowledge the assistance of Mr. Steven J. Long and Mr. Gary McDonald in obtaining specimens. I also appreciate the aid and advice of Mr. James R. Lance in preparing the manuscript.

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Two New Records of *Cratena abronia*

BY

STEVEN J. LONG

126 Esparto Avenue, Pismo Beach, California 93449

ON JUNE 11, 1968, a single specimen of *Cratena abronia* MACFARLAND, 1966 was collected by the author at Dino-saur Cave in the north end of Pismo Beach, San Luis Obispo County, California. The specimen was found in the mid-tide zone on *Desmarestia herbacea* (TURNER, 1808). The specimen measured 5 mm in length, and matched well MACFARLAND's description and illustration of the species. Mr. Richard A. Roller, of San Luis Obispo, California, made a series of color transparencies of the animal and extracted the radula to permit corroboration of the identification. The radula has been preserved in alcohol.

ON JUNE 12, 1968, a second *Cratena abronia* was taken at the south end of Sunset Palisades, about 2 miles north of the first collecting point. This specimen was found in the same tidal region, also on *Desmarestia herbacea*. This animal was in poor condition, having lost several cerata.

It measured 5 mm in length when alive; it was preserved in alcohol for later study.

Cratena abronia was described from several specimens collected at Point Pinos, Monterey Bay, California (36°38' N; 121°55' W). Pismo Beach is located at 35°09' N and 120°38' W. This constitutes a southward range extension of about 230 miles.

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What is *Macoma truncaria* DALL?

BY

EUGENE V. COAN

Department of Biological Sciences, Stanford University
Stanford, California 94305

(1 Text figure)

WHILE STUDYING TYPE SPECIMENS of West American tellinaceans at the United States National Museum, I photographed and sketched the unique holotype of *Macoma truncaria* DALL, 1916, described from between Cape Halkett and Garry Creek [as "River"] on the Arctic coast of Alaska. A brief synonymy is as follows:

DALL, 1916a: 37 [nomen nudum]

DALL, 1916b: 414

DALL, 1921: 48

OLDROYD, 1925: 177

BURCH, 1945: 15



Figure 1

"*Macoma*" *truncaria* DALL, 1916, holotype, USNM 210916, $\times 2.4$
Drawing by Mr. Perfecto Mary

The holotype, USNM 210916, a broken pair with only the left valve complete, measures 15 mm in length and proves to be a small, thickened specimen of *Thracia* (*Crassithracia*). It seems closest to *T. (C.) beringi* DALL, 1915, but the correct allocation would require careful study by one more familiar with the several circum-Arctic species of the genus than I. A line drawing is here provided for the use of other workers.

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Spawning Notes, II. - *Mitra dolorosa*

BY

FAY H. WOLFSON

San Diego Natural History Museum,
 San Diego, California 92115

(3 Text figures)

NO SPAWNING BY *Mitra* (*Strigatella*) *dolorosa* DALL, 1903 had been noted during field trips to Bahía de los Angeles, Baja California, Mexico in April, August, September and December 1967 or in January and April 1968. However, on 23 July 1967 and again on 25 May 1968, I observed spawning at approximately mid-tide level during low tide. In both cases, eggs were being deposited on a small stone situated beneath larger overhanging rocks. There were 2

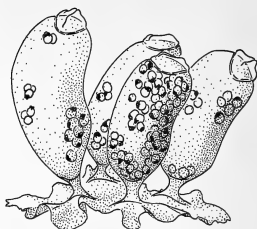


Figure 1

Four capsules of the cluster; lateral view



Figure 2

Detail of capsule, top view



Figure 3

Detail of capsule, side view

individuals on the stone in July and 5 on the stone in May, although in each case only a single individual appeared to be in the process of oviposition. Approximately 50 capsules, forming an irregular ellipse, had been extruded in both instances.

The translucent sausage-shaped capsules rest lightly against each other. Each tapers to a thin stalk which flares into a basal membrane by which the cluster is attached to the substrate (Figure 1). The capsules aver-

age 1.04×2.16 mm in size, with a range of from 0.88×1.91 mm to 1.17×2.35 mm.

An oval inner membrane completely fills the "sausage" and contains approximately 100 opaque, cream-colored eggs, many of which bear a small cap of darkly pigmented cells. The eggs average 0.147 mm in greatest diameter and appear to be distributed in random clumps.

Figures 2 and 3 show the raised, thickened structure situated at or near the top of the capsule. Rupturing of the thin membrane between the "lips" in the center of the structure presumably provides an exit at hatching time.

The figures were drawn by Anne Acevedo of the San Diego Museum of Natural History.

Littorina littorea in California (San Francisco and Trinidad Bays)

BY

JAMES CARLTON

521 Mandana Boulevard, Oakland, California 94610

A SINGLE LIVING SPECIMEN of the common Atlantic periwinkle, *Littorina littorea* LINNAEUS, 1758 was collected by the writer at Berkeley, in San Francisco Bay, California, on July 11, 1968, approximately 300 m north of the foot of Ashby Avenue, along the East Shore Highway. The animal was in a rock crevice, and despite an hour's search, no additional specimens were located. The present specimen measures 15.7 mm in length and 13.8 mm in width.

Littorina littorea is known from the Pacific coast of North America through the collection of at least 5 specimens in Deception Pass, Puget Sound, Washington, in 1937 (HANNA, 1966). The hypotype illustrated by HANNA was compared with the present specimen and its identification confirmed by Dr. Leo G. Hertlein of the California Academy of Sciences. All 5 specimens from Washington bear opercula, indicating live collection.

In addition, there are 2 specimens in the collections of the California Academy of Sciences (cat. no. 39464) from Trinidad Bay, California (just north of Humboldt Bay), collected alive by Dr. Doris K. Niles on July 28, 1942, but not received at the Academy until 1965, too late for inclusion in Dr. Hanna's paper. The specimens measure 27.0 mm in length by 21.4 mm in width, and 26.1 mm by 20.4 mm.

It may be noted here that no specimens of *Littorina littorea* from Pacific coast localities have been found in the Stanford University collection (Dr. A. Myra Keen, personal communication), nor in the collection of the Department of Paleontology of the University of California, Berkeley (examined by the writer through the courtesy of Dr. Joseph H. Peck).

Thus, living *Littorina littorea* are now known on the Pacific coast from Puget Sound, Washington; Trinidad and San Francisco Bays, California. The collection of additional specimens from San Francisco Bay will help to determine whether this mollusk has been able to establish a reproducing population, or whether the present collection represents only one of a limited number of individuals directly transported to the Bay. Dr. Niles reports (*in litt.*) that she has been unable recently to find this species in Trinidad Bay and there are no known subsequent reports from Puget Sound.

It is interesting to note that the discovery of *Littorina littorea* on the Pacific coast has proceeded chronologically southward. A similar situation has prevailed since the early part of the nineteenth century on the Atlantic coast of the United States, where this mollusk has been recorded as progressively moving southward, from Nova Scotia (since 1840) to Maryland (in 1959) (WELLS, 1965). Its probable southern limit is correlated with a 21° C mean water isotherm (WELLS, *op. cit.*). There is no indication, however, that the Pacific coast occurrences illustrate a natural southward movement, but rather it appears that this species was accidentally introduced into the 3 known localities on as many different occasions. The progressively southern occurrence of *L. littorea* on the Pacific coast is apparently a coincidence with the Atlantic coast phenomenon.

The means of introduction of this northern Atlantic snail into San Francisco Bay, and earlier into Trinidad Bay, remain problematical. The abundance of exotic mollusks in the San Francisco Bay region [e. g., the Atlantic species *Modiolus demissus* (DILLWYN, 1817), *Mya arenaria* LINNAEUS, 1758, *Gemma gemma* (TOTTEN, 1834), *Nassarius obsoletus* (SAY, 1822), *Urosalpinx cinereus* (SAY, 1822), *Busycotypus canaliculatus* (LINNAEUS, 1758), and the Oriental species *Tapes japonicus* DESHAYES, 1853, and *Musculus senhousei* (BENSON, 1842)], as well as a number of other invertebrates, supposedly largely introduced through oyster transport, well illustrates the ease with which exotic species have established themselves locally. Almost all of the accidentally introduced Atlantic mollusks arrived when shipments of the American oyster, *Crassostrea virginica* (Gmelin, 1791) were still being transported on a large scale to the Pacific

ic coast, before 1935 (HANNA, 1966). The possibility that this rather conspicuous species was introduced with *Crassostrea* into San Francisco Bay more than 30 years ago, and has been overlooked, is not probable, when the continuous collecting and numerous field expeditions by local biologists, students, and shell collectors are considered. The possibility that the large introduced Atlantic whelk, *Busycotypus canaliculatus*, was overlooked for a period of 10 years (between 1938 and 1948) is held improbable by STOHLER (1962). However, small shipments of *Crassostrea* from the Atlantic coast of the United States are still being received for placement in San Francisco Bay, and between 1962 and 1967 plantings of oyster spat were made 2 or 3 times in the southern portion of the Bay on an experimental basis only (Mr. W. Dahlstrom, Calif. Dept. Fish and Game, personal communication). It is possible that juvenile *Littorina*, or *Littorina* eggs, may have been introduced with these shipments.

A second method by which this snail may have been introduced involves the Atlantic quahog, *Mercenaria mercenaria* (LINNAEUS, 1758). The report by NORTH (1963), cited by HANNA (1966), concerning the planting of 2000 *Mercenaria* in San Francisco Bay in 1963 is in error (personal communications from Dahlstrom and Dr. V. Loosanoff), and thus there have apparently been no official plantings of this bivalve in the Bay (Dahlstrom, Loosanoff, and J. A. Aplin, personal communications). However, in January, 1968 several living *Mercenaria* were discovered at Coyote Point, San Mateo County, in San Francisco Bay, together with numerous specimens of the venerid *Tapes japonicus* by Mr. R. Setzer, a graduate student at San Francisco State College (personal communications from Setzer and Mr. D. Chivers, Calif. Acad. Sci.). This small and questionably established population is apparently the result of an independent effort by an unknown person, and was without the planting permission of the California Department of Fish and Game (Aplin, personal communication). In addition, local restaurants are continually importing Atlantic quahogs, and may dump spoiled shipments into the Bay. It is also known that many independent introductions of Atlantic oysters and clams have been made into the San Francisco Bay region, and that, additionally, plantings made officially in other California bays may be brought into San Francisco Bay by private persons (Loosanoff, personal communication). It is thus also quite possible that specimens of *Littorina* may have been transported recently from the Atlantic coast with *Mercenaria*.

The present shell with the operculum has been deposited in the Department of Geology, California Academy

of Sciences (catalogue no. 40981); the animal has been placed in the wet collections of the Department of Invertebrate Zoology of the same institution.

ACKNOWLEDGMENTS

For generous assistance with various details and in the examination of specimens in the collection of the California Academy of Sciences, I thank Dr. Leo G. Hertlein. Mr. Dustin Chivers of the Academy kindly aided with the curating of the specimen and contributed suggestions and advice as did Mr. John Holleman of Merritt College, Oakland. Dr. Joseph Peck generously permitted me to examine the large shell collection of the Department of Paleontology of the University of California, and Dr. Myra Keen kindly provided information about the Stanford collections. Dr. Doris K. Niles also furnished additional information concerning the material from Trinidad Bay. I wish to thank also Mr. J. Allan Aplin, Mr. Walter Dahlstrom, Dr. Victor Loosanoff, and Mr. Robert Setzer for communicating to me their records of *Mercenaria* or *Crassostrea* in San Francisco Bay.

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Revision of "Introduced Mollusks of Western North America"

JAMES CARLTON

521 Mandana Boulevard, Oakland, California 94610

A REVISION OF G. DALLAS HANNA's recent paper on the introduced Mollusca of western North America (HANNA, 1966) is currently being undertaken under the supervision

of Allyn G. Smith, Associate Curator, Department of Invertebrate Zoology, California Academy of Sciences, San Francisco. Geographic regions covered include California, Oregon, Washington, and British Columbia. Workers with any corrections, comments, suggestions, or new records are encouraged to send such information to Mr. Smith at the Academy, Golden Gate Park, San Francisco, California 94118.

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1966. Introduced mollusks of western North America.
Occ. Pap. Calif. Acad. Sci. no. 48: 108 pp.; 85 figs.; 4 pls.
(16 February 1966)

A. M. U.

AT THE ANNUAL MEETING of the American Malacological Union at Corpus Christi, Texas, the following officers were elected to serve during 1968-1969:

- Dr. Joseph Rosewater, *President*
Dr. Alan G. Solem, *Vice-President*
Dr. Bruce G. Campbell, *Second Vice-President*
Mrs. Margaret C. Teskey, *Secretary*
Mrs. H. B. Baker, *Treasurer*
Mr. Morris K. Jacobson, *Publications Editor*
Councillors-at-Large elected are: Donald R. Moore,
Robert Robertson, Donald R. Shasky, Myra Taylor.
The 1969 annual meeting will be held June 21 to 25 at Marinette, Wisconsin.

Margaret C. Teskey, *Secretary*.

A. M. U.

Pacific Division

AT THE ANNUAL MEETING at Asilomar, California, in June 1968 the following officers were elected to serve for an indefinite period:

- Dr. Bruce G. Campbell, *Chairman*
Dr. James H. McLean, *Vice-Chairman*
Mrs. Ruth French, *Secretary and Treasurer*
No meetings are planned for the near future. The annual assessment of 50 cents per person was rescinded.
The Honor Award, bestowed by the Division from time to time, was presented to Dr. Leo G. Hertlein of the California Academy of Sciences for his continued outstanding contributions to Malacology.

W. S. M.

AT THE FIRST ANNUAL MEETING at Asilomar, California, in June 1968, the Society adopted its bylaws. Officers elected are:

- Dr. William K. Emerson, *President*
Dr. A. Myra Keen, *First Vice-President*
Mr. Eugene V. Coan, *Second Vice-President*
Mrs. R. (Forrest) Poorman, *Treasurer*
Mrs. Bernadine Hughes, *Secretary*
As *Representatives-at-Large* were elected: Dr. Judith Terry, and Miss Betsy Harrison.

At the meeting a contest was held for the best paper submitted by a college student. A first and a second prize was awarded to Miss M. T. Vassallo and Mr. S. K. Webster, respectively.

The second annual meeting will be held from June 18 to 21, 1969, at Asilomar.

U. M. E.

AT THE THIRD CONGRESS of the European Malacological Union in Vienna, September 2 to 7, 1968, the following officers were elected:

- Dr. Eugène Binder (Geneva), *President*
Dr. F. E. Loosjes (Wageningen), *Vice President*
Dr. A. Zilch (Frankfurt), *Secretary*
Dr. Lothar Forcart (Basle), *Treasurer*

The next meeting of the Unitas Malacologica Europaea will take place in Geneva, Switzerland in the year 1971.

Important Notices

Because of the changed rules affecting second class mail matter, we will no longer be able to include the customary reminders in our January issue, nor can we attach any flyers to our journal henceforth. We shall, from now on, print a statement when dues-renewal time has arrived or announcements regarding special publications in our NOTES & NEWS column.



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If your address is changed it will be important to notify us of the new address at least **six weeks** before the effective date, and not less than six weeks before our regular mailing dates. Because of a number of drastic changes in the regulations affecting second class mailing, there is now a sizeable charge to us on the returned copies as well as for our remailing to the new address. We are forced to ask our members and subscribers for reimbursement of these charges; further, because of increased costs in connection with the new mailing plate, we also must ask for reimbursement of that expense. Effective January 8, 1968 the following charges must be made:

- change of address - \$1.-
- change of address and re-mailing of a returned issue - \$2.-.

We must emphasize that these charges cover only our actual expenses and do not include compensation for the extra work involved in re-packing and re-mailing returned copies.

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At a Regular Membership Meeting of the CALIFORNIA MALACOOLOGICAL SOCIETY, Inc. the following policies were adopted by unanimous vote:

Effective January 1, 1967 there will be an initiation fee of \$2.- for persons joining the Society. NOTE: No Institutional Memberships are possible in the C. M. S., Inc.

Members receive *The Veliger* free of further charges and are entitled to purchase one copy of any supplement published during the current membership year at a special discount (to be determined for each supplement).

Membership renewals are due on or before April 15 each year. If renewal payments are made after April 15 but before March 15 of the following year, there will be a re-instatement fee of \$1.-. Members whose dues payments (including the re-instatement fee) have not been received by the latter date, will be dropped from the rolls of the Society. They may rejoin by paying a new initiation fee. The volume(s) published during the time a member was in arrears may be purchased, if still available, at the regular full volume price plus applicable handling charges.

Manuscripts received up to February 14 each year will be considered for publication in our July issue; May 14 is the deadline for the October issue, August 14 for the January issue and November 14 for the April issue. For very short papers of less than 500 words (including title, etc.) the deadlines are one month later than those given above, provided that these short notes are important enough to warrant preferential treatment. It is, however, understood that submission of a manuscript before the dates indicated is not a guarantee of acceptance.

CALIFORNIA MALACOOLOGICAL SOCIETY, Inc.

is a non-profit educational corporation (Articles of Incorporation No. 463389 were filed January 6, 1964 in the office of the Secretary of State). The Society publishes a scientific quarterly, the VELIGER. Donations to the Society are used to pay a part of the production costs and thus to keep the subscription rate at a minimum. Donors may designate the Fund to which their contribution is to be credited: Operating Fund (available for current production); Savings Fund (available only for specified purposes, such as publication of especially long and significant papers); Endowment Fund (the income from which is available. The principal is irrevocably dedicated

to scientific and educational purposes). Unassigned donations will be used according to greatest need.

Contributions to the C. M. S., Inc. are deductible by donors as provided in section 170 of the Internal Revenue Code (for Federal income tax purposes). Bequests, legacies, gifts, devices are deductible for Federal estate and gift tax purposes under section 2055, 2106, and 2522 of the Code. The Treasurer of the C. M. S., Inc. will issue suitable receipts which may be used by Donors to substantiate their respective tax deductions.

Endowment Fund

At a Regular Membership meeting of the Society in November 1968 a policy was adopted which, it is hoped, will assist in building up the Endowment Fund of the Society.

An issue of the journal will be designated as a Memorial Issue in honor of a person from whose estate the sum of \$5000.- or more has been paid to the Veliger Endowment Fund. If the bequest is \$25 000.- or more, an entire volume will be dedicated to the memory of the decedent.

In the face of continuous rises in the costs of printing and labor, the income from the Endowment Fund would materially aid in avoiding the need for repeated upward adjustments of the membership dues of the Society. It is the stated aim of the Society to disseminate new information in the field of malacology and conchology as widely as possible at the lowest cost possible.

ABOUT SUPPLEMENTS

Many of our members desire to receive all supplements published by the Society. Since heretofore we have sent supplements only on separate order, some members have missed the chance of obtaining their copy through oversight or because of absence from home. It has been suggested to us that we should accept "standing orders" from individuals to include all supplements published in the future. After careful consideration we have agreed to the proposal. We will accept written requests from individuals to place their names on our list to receive all future supplements upon publication; we will enclose our invoice at the same time. The members's obligation will be only to pay promptly upon receipt of the invoice.

Requests to be placed on this special mailing list should be sent to the Manager, Mrs. Jean M. Cate, 12719 San Vicente Boulevard, Los Angeles, California 90049.

METHODS & TECHNIQUES

A Method
of Tagging Mollusks Underwater

BY

RICHARD J. ROSENTHAL

Westinghouse Ocean Research Laboratory
San Diego, California 92121

(1 Text figure)

INTRODUCTION

THE TAGGING OF SUBTIDAL marine mollusks has usually been done at the surface. Most of these tagging studies have involved a small number of economically important species. COX (1962) studied the red abalone, *Haliotis rufescens* SWAINSON, 1822, along the California coast, attaching the tags by wire threaded through the respiratory holes of the shell. NEWMAN (1966) used a disc tag fastened by a nickel pin passing through a respiratory pore to study the movements of the South African abalone, *H. midae* LINNAEUS, 1758. More recently, FORSTER (1967) described tagging the British ormer, *H. tuberculata* LINNAEUS, 1758, with disc tags using resin cement as an adhesive. A study being conducted off southern California by T. C. Tutschulte (personal communication) on the migratory movements of *Haliotis* spp. utilizes time-lapse photography and luminous tags cemented with epoxy to the shells *in situ*.

In the first three investigations the animals were collected by divers and the majority of the tagging was completed above water. Surface tagging may introduce more variables than are necessary, since the organisms are removed from their normal environmental situation and exposed for a brief period of time to unnatural conditions. Placing the animals back in their original habitat after marking does not guarantee that they will return to a "normal" pattern of behavior. Tagging at the surface may also be impractical when dealing with subtidal mollusks which are solidly attached or cemented to the substrate.

This study was undertaken to perfect a method for tagging hard-shelled mollusks underwater, with a minimum amount of disturbance to the animals and their surroundings.

MATERIALS AND METHODS

A commercially available non-toxic epoxy¹ was used to attach the tag to the shell surface. This particular epoxy was selected because it hardens thoroughly underwater. The curing time depends on the water temperature and the thickness of the epoxy used on each shell. Mixing the resin and catalyst in a 1:1 volume on the surface was found to be the best procedure, since attempts at mixing the two components underwater proved unsatisfactory. The resin-catalyst mixture is grey-white in color, which may be suitable for mollusks having lightly pigmented shells. For those with darker shells, a black pigment can be added to darken the epoxy, thereby lessening the attention of predators or the attraction of curious fishes to the tagged mollusks.

Engraved disc tags made from gravoply were used to increase the permanence of the number and ease of reading underwater. The tags and newly mixed epoxy were taken underwater in separate containers by scuba divers. When suitable animals were located, the overall shell length was recorded and the tagging region of the shell was cleaned with a wire brush. Then the epoxy was applied to the mollusk shell and a numbered tag was pressed into the epoxy (Figure 1).

RESULTS AND DISCUSSION

A tagging experiment on Kellet's Whelk, *Kelletia kelletii* (FORBES, 1850) was started in December 1967 to acquire more knowledge about the ecology and life history of this marine gastropod. A total of 120 *K. kelletii* have been tagged in depths of 15 to 20 m of water at 3 different localities off San Diego County, California. The taggings have been conducted off of Point La Jolla, Mission Beach, and along an ecological survey line near Del Mar. These 3 subtidal areas were selected because they differ substantially in substrates and species composition.

A great deal of the tagging took place during the reproductive season (March-June), when large numbers of these whelks were copulating and laying eggs at the 3 localities. During subsequent dives, copulation and egg laying was observed in tagged individuals — an indication that the tagging had not disturbed their behavioral activities.

The tags remain securely attached to the shells of the animals located to date (September 1968), 263 days after

¹ Sea Go-In Poxxy Putty — 1324; Permalite Plastics Corporation, Costa Mesa, California.

the initial 11 *Kelletia kelletii* were tagged on December 11, 1967. Success in finding these motile benthonic animals is largely dependent upon the visibility underwater, although searching from a permanently emplaced survey line eases the difficulty in locating them.

Other mollusks have been successfully tagged using this method: The rock scallop, *Hinnites multirugosus* (GALE, 1928); the red abalone, *Haliotis rufescens*; and the wavy top shell, *Astraea undosa* (WOOD, 1828).

The size of the mollusk does not present a problem, since the epoxy can be shaped to conform to the characteristics of the outer shell and the disc tags sized accordingly. This reduces any hindrance to the movement of the animal and the possibility of the epoxy coming in contact with the animal's living tissue (Figure 1).

The advantages of this technique appear to be the permanence of marking, and the fact that tagging can be completely carried out underwater with a minimum amount of disturbance to the subjects and their environment.

ACKNOWLEDGMENTS

I am particularly grateful to Dr. W. D. Clarke for valuable advice and encouragement, and to Mr. R. E. Bower for technical assistance in the field.

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A Method of Color Preservation in Opisthobranch Mollusks

BY

GORDON A. ROBILLIARD

Department of Zoology
University of Washington
Seattle, Washington 98105

INTRODUCTION

COLOR AND COLOR PATTERN are useful taxonomic characters in the opisthobranch mollusks. However, I know of no published reports describing a method of preserving color in opisthobranchs. Instead, it is usually assumed that the colors will fade or be bleached out in formalin,



Figure 1

The drawing shows a tagged *Kelletia kelletii* with a numbered disc embedded in epoxy and cemented to the dorsal region of the shell.

alcohol, or other preservatives. Color is usually preserved in color photographs or field notes or both.

TOYAMA & MIYOSHI (1963) and WALLER & ESCHMEYER (1965) successfully employed an antioxidant, butylated hydroxytoluene (hereafter referred to as Ionol C. P. -40), to preserve some colors in fish and a prawn. WALLER & ESCHMEYER (*op. cit.*) used 1, 10, and 20 cc of Ionol C. P. -40 per 4500 cc of 10% formalin to make the test solutions (0.02%, 0.22%, and 0.44% concentrations respectively). Eighteen months later, they found that the color of fish in the 0.44% solution was best preserved, but preservation of colors of fish in other test solutions was superior to that of fish in untreated formalin solution.

In this note, I report the results of testing this technique on opisthobranchs from 3 orders (Cephalaspidea, Sacoglossa, and Nudibranchia) with emphasis on the nudibranchs.

MATERIALS AND METHODS

A stable emulsion was formed by vigorously stirring Ionol C. P. -40 into hot sea water (55° to 65° C) (Shell Technical Bulletin, IC:67-16). Concentrations of Ionol C. P. -40 used in the emulsions gave final dilutions of 0.1% to 0.5% Ionol C. P. -40 by volume. Formalin was added to this emulsion to give a final concentration of 5% formalin by volume (hereafter referred to as Ionol C. P. -40 emulsion). Ionol C. P. -40 is also readily soluble in alcohol.

Most of the opisthobranchs were relaxed for 1 to 5 minutes, depending on size, with succinylcholine chloride (BEEMAN, 1968). A few, especially the Cephalaspidea, were relaxed for 2 to 8 hours in propylene phenoxetol using 1% by volume of propylene phenoxetol in sea water (OWEN, 1955; OWEN & STEEDMAN, 1958).

Small animals (< 1.5 to 2.0 cm long) were then put directly into Ionol C. P. -40 emulsion. Formalin diffuses inward rapidly enough to preserve the internal tissues. Larger animals (> 2 cm long) were injected with a small amount of 5% formalin in sea water without Ionol C. P. -40, to preserve the internal tissues, then put into the Ionol C. P. -40 emulsion.

The Ionol C. P. -40 emulsion was not injected into the animal because it eventually forms an oily film in the body cavities and over the tissues. This is particularly undesirable if the animals are to be dissected. In any case, there are few internal organs in an opisthobranch in which color is distinctive or taxonomically important.

The method was tested on 1 sacoglossan, *Elysia hedgethi* MARCUS, 1961; 2 cephalaspideans, *Haminoea* sp.,

and *Aglaja diomedea* (BERGH, 1893); and 30 species of nudibranchs of which 12 were dorids, 12 were dendronotaceans, and 6 were aeolids.

RESULTS

Of the concentrations tested, 0.3% Ionol C. P. -40 emulsion resulted in maximal color retention and was used for most of the specimens.

Stored in bottles in glass-door cabinets, the specimens in Ionol C. P. -40 emulsion have been exposed to normal artificial lighting, but protected from direct sunlight, for up to 2 years. In most cases, the original color has been retained albeit with varying degrees of fading in some species. The color of virtually all specimens stored under similar conditions, but in untreated 5% formalin in sea water, has faded markedly or disappeared.

Some colors are preserved better and longer than others. The yellow body color and black spots of *Anisodoris nobilis* (MACFARLAND, 1905) and *Archidoris montereyensis* (COOPER, 1862) are well preserved as are the yellow and orange pigments of *Triopha carpeniteri* (STEARNS, 1873). The orange on the cerata of *Laila cockerelli* MACFARLAND, 1905 is completely preserved while the orange on *Hermisenda crassicornis* (ESCHSCHOLTZ, 1831) faded slightly. Slight fading has occurred in the orange-red body color of *Rostanga pulchra* MACFARLAND, 1905. The salmon-pink body color of *Tritonia festiva* (STEARNS, 1873) and *T. gilberti* (MACFARLAND, 1966) and the orange body color of *T. (Tochuina) tetraquetra* (PALLAS, 1788) fade only slightly. The same is true of the brown blotches of *Diaulula sandiegensis* (COOPER, 1862). Many specimens of *Dendronotus* spp. have been preserved in Ionol C. P. -40 emulsion and the colors - white, metallic orange, brown, magenta, yellow, mauve, purple, pink, grey, red - have faded slightly over periods of up to 2 years. The orange body color and white spots of *Dirona aurantia* HURST, 1965 and the white pigment on the cerata of *D. albolineata* COCKERELL & ELIOT, 1905 fade somewhat. The dark green body color of *Elysia hedgethi* and the black (or dark purple) of *Aglaja diomedea* have faded very little.

In a few cases, the color faded markedly or completely disappeared. The chocolate brown color of *Onchidoris bilamellata* (LINNAEUS, 1767) faded to about a third of its original intensity. In *Cadlina marginata* MACFARLAND, 1905, the yellow pigment disappears completely within 12 to 24 hours. The yellow on the notal papillae of *Acanthodoris hudsoni* MACFARLAND, 1905 fades markedly over a week. Structural colors, such as blue on *Hermisenda crassicornis* and other opisthobranchs (BÜRGIN,

1965, BÜRGIN-WYSS, 1961) usually disappear when the animal is killed and they cannot be preserved by an antioxidant.

CONCLUSION

The use of an antioxidant such as Ionol C. P. -40 with a preservative seems to be a successful and relatively simple method of preserving most colors in the opisthobranchs. However, on the basis of this study, it is not possible to generalize about which colors will be preserved between different taxa or even within a certain taxon. Further experimentation with Ionol C. P. -40 will likely demonstrate a more widespread applicability as well as delineating more precisely which colors will or will not be preserved.

The optimal concentration proved to be 0.3% Ionol C. P. -40 by volume in a solution of 5% formalin in sea water.

Color retention is an obvious advantage to the taxonomist in that it allows him to augment the description of a species. This is especially true in soft-bodied animals like opisthobranchs where color, though quite variable intraspecifically, often serves as a guide in species identification.

ACKNOWLEDGMENTS

I wish to extend my thanks to Brian Case, University of Manitoba, for first bringing the method to my attention and to the Shell Chemical Company, Industrial Chemicals Division (Portland Office) for the sample of Ionol C. P. -40. I am grateful to Dr. Alan J. Kohn for reading the manuscript and for his suggestions. This work was supported by a Special Scholarship from the National Research Council of Canada.

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BOOKS, PERIODICALS, PAMPHLETS

Between Pacific Tides

by EDWARD F. RICKETTS & JACK CALVIN, Fourth edition, revised by JOEL W. HEDGPETH. September 19, 1968. xiv + 614 pp.; 8 color plates; 302 text figures.

Stanford University Press, Stanford, California. \$10.-.

This classic work on the ecology and natural history of plants and animals inhabiting the Pacific shores in the area between the low and the high tide marks was written, originally, "for laymen, for beginners . . ." but it has filled a need far beyond that envisioned by Ed Ricketts. Because of the thoroughly annotated bibliography, the book has become an important first source for many serious investigators and an indispensable text book in many courses in invertebrate zoology.

The book has gone through three previous editions, the first two by the original author, and the third edition revised by Dr. Hedgpeth. Each edition was better than the previous one, each updated to include the latest developments in the fields of endeavor covered by the scope of the work.

This fourth edition, again revised and brought up to date, is a worthy successor to the other three editions. Dr. Hedgpeth has brought his critical talents to bear and his influence can be perceived on practically every page, although he has managed beautifully to preserve the original charm of the book. And while a number of the illustrations are the old familiar ones, many have been superseded by better pictures illustrating more precisely what was desired to be called to the reader's attention. Even the color plates have been much improved, although they may perhaps, in a future edition, be printed with a still better technique which will render the delicate colors of the intertidal area more life-like.

We can only say that this new edition is a must for the layman who wishes to become better acquainted with the seashore and its wealth of animals and plants; it is indispensable for the serious student, be he a beginner or advanced; and the professional invertebrate zoologist will find many tidbits of important knowledge in the pages of this book.

There is, however, one part of the book that was not possible in the "good old days" of Ed Ricketts, a part which should be required reading not only for the student of the seashore, but for politicians and all those persons who are in a position to make policy and to decide "what is best for all." To this portion of the book Dr. Hedgpeth brings some of his best thoughts and it is evident from these pages that "conservation" is not a sometime thing for him. It is a truly thought-provoking chapter and it alone would be worth the price of the entire book.

RS

Tidepool Animals from the Gulf of California

by WESLEY M. FARMER. 70 pp.; 4 color plates (with 6 photographs each); 170 line drawings. Wesword Comp., Post Office Box 15333, San Diego, California 92115.

Price, \$6.50. Stiff paper bound.

Since travel into Lower California is increasingly popular, shell collectors from near (San Diego, for example) and far (New York and Teaneck, for example) roam over the sandy beaches and rocky shores of the rich Gulf of California. The climatic conditions are, during a part of the year, very agreeable and collecting thus becomes a pleasant occupation.

For the Pacific coast of North America we have the book by Ricketts and Calvin, as well as a few other, more limited books to help the collector in identifying his loot. Aside from Steinbeck's "The Sea of Cortez" there is no popularly written work available for the Gulf. Or, rather, there was, until now, no such work available.

Mr. Farmer, who was Curator of exhibits at the San Diego Museum of Natural History, has brought together in this booklet a brief description accompanied by an excellent pen-and-ink drawing of somewhat over 100 of the animals one is likely to encounter in the tidepools. His color photographs, especially of his favorite nudibranchs, are superb. His descriptions are pithy and to the point.

It may be anticipated that future editions will be expanded to include many species of invertebrates that are

relatively frequently encountered, although, perhaps not by the person casually strolling along the beaches.

RS

Descriptions of New Species of Gastropods from Clipperton Island

by LEO G. HERTLEIN & EDWIN C. ALLISON. Occas. Papers Calif. Acad. Sci. No. 66; 13 pp.; 13 figs. June 27, 1968.

Nine species of some extremely small (less than $\frac{1}{2}$ mm) to medium sized (50 mm) snails are discussed. Six of these species are new to science.

RS

Kelp Habitat Improvement Project

by WHEELER J. NORTH. 123 pp.; 47 figures; 22 tables. Published after July 1, 1968 by the W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena, California.

This, the fifth annual report, appears to us to be more encouraging than its predecessors inasmuch as the general outlook for the re-establishing of the once thriving kelp beds along the California coast seems more promising. Much detailed information, of value to the student of marine ecology, is contained in these pages. The conservationist also will take heart from the perusal of the report.

RS

Water Quality and Biologic Conditions South Bay Aqueduct

by C. A. McCULLOUGH. State of California Resources Agency, Department of Water Resources. 180 pp.; numerous tables; 1 multiple fold-out; 15 pages with 2 to 4 photographs.

Of particular interest to the malacologist is the part of the report that deals with the Asiatic clam, *Corbicula*.

RS

Age of first Marine Terrace Near Santa Cruz, California

by WILLIAM C. BRADLEY & WARREN O. ADDICOTT. Geol. Soc. America Bull., vol. 79, pp. 1203-1210; 1 table; 1 fold-out insert. September 1968.

THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or other taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, may be published in the column "NOTES and NEWS"; in this column will also appear notices of meetings of regional, national and international malacological organizations, such as A. M. U., U. M. E., W. S. M., etc., as well as news items which are deemed of interest to our Members and subscribers in general. Articles on "METHODS and TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, and PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

Manuscripts should be typed in final form on a high grade white paper, not exceeding 8½" by 11", at least double spaced and accompanied by a clear carbon or photo copy. A pamphlet with detailed suggestions for preparing manuscripts intended for publication in THE VELIGER is available to authors upon request. A self-addressed envelope, sufficiently large to accommodate the pamphlet (which measures 5½" by 8½"), with double first class postage, should be sent with the request to the Editor.

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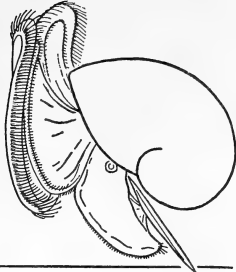
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples, and by increasing indentation.

ORDER, Suborder, DIVISION, Subdivision, SECTION,
SUPERFAMILY, FAMILY, Subfamily, Genus, (Subgenus)
New Taxa

The Muricidae of Fiji

Part II - Subfamily Thaidinae

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands, and Division of Mollusks, Smithsonian Institution
U. S. National Museum, Washington, D. C. 20560

(Plates 47 to 49; 21 Text figures; 1 Map)

THIS IS THE NINTH PART in the series of faunal monographs dealing with the marine mollusca of the Fiji Islands; it is the second part of the Muricidae of Fiji, the first having been published by the author in 1967.

Species recorded from Fiji have an Indo-Pacific distribution and none of the species is endemic to the Fiji Islands. For notes on the geography of the Fiji Islands and other pertinent data see CERNOHORSKY, 1964.

TAXONOMY

The systematics of the muricid subfamily Thaidinae is presently in a state of flux. Several applications are pending with the International Commission on Zoological Nomenclature (BRADLEY & PALMER, 1963; KEEN, 1964, 1964a) for either a suppression or validation of thaidine genera, type species and even family groups. Since rulings by the ICZN on these applications cannot be anticipated, pre-application taxonomy has largely been adopted.

Existing taxonomic treatments of the thaidine group are not only few but highly conflicting in opinion; some workers retain the thaidine group of species within the family Muricidae while others assign them to a separate family Thaididae. POWELL (1962) arranged the Neozelanic species of *Thais* s. l. under the family Thaididae. IREDALE & McMICHAEL (1962) accorded familial rank to East Australian Thaidinae, Typhinae and Trophoninae. KEEN (1958) considers West American Trophoninae and Typhinae to be of muricid stock but separates Thaididae as a separate family.

Workers who study the shell, animal, ecology, and embryology of thaidine species as a single biological unit disagree with an elevation of Thaidinae to familial rank and consider the various muricid groups under discussion to be of a common phylogenetic origin. COOKE (1919), THIELE (1929), ARAKAWA (1962), WU (1965a), HARE

& KOSUGE (1966, 1967), and ORR-MAES (1967) are some of the workers who retain thaidine genera in the family Muricidae.

As far as tropical Pacific thaidine species are concerned, there seems to be little or no zoological reason for a separation from the Muricidae. In shell morphology, animal, anatomy, radula, habitat, feeding requirements, and geographical distribution, Thaidinae are so closely related to other muricid genera that existing natural affinities and common phylogenetic origin can hardly be concealed. There is no decided gap between the tritonaline genera *Urosalpinx* STIMPSON, 1865 and *Muricopsis* BUCQUOY, DAUTZENBERG & BOUGE, 1882, on the one hand and the *Morula-Cronia* group in Thaidinae on the other; here the characters are transitional and rather nebulous.

THE THAIDINE RADULA

A generic grouping based on shell characters alone disagrees with a classification based on radula features. COOKE (1919) contended that "an examination of the radula of the various species of *Thais* lends little support to the groupings of that genus, based on the forms of the shell, to which are given the names of *Stramonita*, *Tribulus*, *Polytropha*, *Thalessa*, etc." He indicated that certain groupings are desirable, but rather in a different direction.

How generic groupings based on shell characters alone cut right across an arrangement based on radular evidence is best illustrated by *Mancinella* LINK, 1807. The two species *M. mancinella* (LINNAEUS, 1758) and *M. tuberosa* (RÖDING, 1798) do have a common radula pattern which differs from radula features of some species of *Thalessa* H. & A. ADAMS, 1853 and would support a generic separation based on shell characters (lirate labrum). *Thais aculeata* DESHAYES, 1844 (= *T. hippocas-*

tanum auct.) is generally assigned to *Thalessa* on the basis of shell characters, but belongs to *Mancinella* on the basis of radula features. The radula of the type species of *Thais* RÖDING, 1798, i.e. *T. nodosa* (LINNAEUS, 1758) is of the same pattern as the radula of the *Mancinella* group, according to COOKE's description (*op. cit.*, as *T. neritoides*); the variant *Thais nodosa* var. *ascensionis* (QUOY & GAIMARD, 1833) [= *T. meretricula* RÖDING, 1798] has, however, the radular pattern of *Thalessa*. It is realized that there is a certain amount of variation in muricid radula pattern within a species, but the differences between the radula of a species and a variety as described by COOKE (*op. cit.*) exceed the expected range of variation. Should COOKE's results prove to be correct, and *Thais nodosa* and the variety *T. meretricula* are indeed conspecific, then the variability of the thaidine radula is much greater than anticipated.

The radulae of the *Thais-Mancinella-Thalessa* group shade through gradual stages from a simple tricuspid rhachidian of *Mancinella* to the elaborate pattern of *Thais* and *Thalessa* with bifid side cusps, numerous side denticles and prominent outer cusps. The radulae of *Drupa* RÖDING, *Drupella* THIELE, *Drupina* DALL and *Morula* SCHUMACHER have a sufficiently modified radula

and shell to merit recognition of these groups as full genera.

ACKNOWLEDGMENTS

I would like to record my thanks to Dr. Harald A. Rehder, Smithsonian Institution, U.S. National Museum, Washington, for the research facilities made available by the Division of Mollusks, and for his valuable discussions and opinions on nomenclatural problems.

Thanks are due to Dr. E. Binder, Muséum d'Histoire Naturelle, Geneva; Dr. N. Tebble, British Museum (Natural History) London and Mr. J. O'Grady, Linnean Society, London, for the opportunity afforded me to examine the type collections of Muricidae in these Institutions.

Fiji collectors have generously made available their collections for this study, and my thanks are due to Mr. and Mrs. R. F. Brown, Nausori; Mr. and Mrs. F. Freitag, Suva; Mr. E. Gardner, Suva; Mrs. C. Jameson, Lautoka; and Mr. A. Jennings, Auckland, New Zealand.

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(* indicates a homonym or synonym)

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NEOGASTROPODA

MURICACEA

MURICIDAE

Thaidinae

Thais RÖDING, 1798

Thais RÖDING, 1798, Mus. Bolten., p. 54. Type species by SD (STEWART, 1927) *T. lena* RÖDING, 1798 = *Nerita nodosa* LINNAEUS, 1758

Thais aculeata (DESHAYES & MILNE EDWARDS, 1844)

(Plate 47, Figure 1)

- *Thais hippocastanum* auctt. (non *Murex hippocastanum* LINNAEUS, 1758)
1822. *Purpura hippocastanum* LAMARCK, Anim. s. vert., 7: 258 (non *Murex hippocastanum* LINNAEUS, 1758)
1836. *Purpura hippocastanum* KIENER, Spec. gén. icon. coq. viv., 7: 52; pl. 12, figs. 33, 33a (non *Murex hippocastanum* LINNAEUS, 1758)
1844. *Purpura aculeata* DESHAYES & MILNE EDWARDS, Anim. s. vert., 10: 104 (nom. nov. pro *P. hippocastanum* KIENER, 1836)
1919. *Thais hippocastanum* LAMARCK, COOKE, Proc. Malacol. Soc. London, 13: 95 (descr. radula) (non *Murex hippocastanum* LINNAEUS, 1758)
1929. *Purpura* (*Thalessa*) *pseudohippocastanum* DAUTZENBERG, Contrib. Faun. Madag., p. 221 (nom. nov. pro *P. hippocastanum* KIENER, 1836)

Shell: Dirty grey in colour, nodules occasionally dark brown. Sculptured with 4 rows of blunt or spinose nodes on the body whorl and 1 - 2 rows on earlier whorls; interstices spirally striate. Interior of aperture bluish-white or light violet, edge of labial lip purplish-brown and denticulate; columella chocolate-brown, occasionally banded with white, sculptured anteriorly with 1 - 2 weak plicae.

L: 24 - 55 mm; W: 66 - 79%; HA: 63 - 75%

Type Locality: None.

Habitat: On reefs, under coral and basalt rocks, in shallow water. Uncommon.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: *Murex hippocastanum* LINNAEUS, 1758 is not the *Thais hippocastanum* of authors. The Linnaean collection of the Linnean Society in London contains 3 specimens in the box for *Murex hippocastanum* which represent 2 different species; one specimen is the *Mancinella tuberosa* (RÖDING, 1798) and 2 specimens are the *Volema galeodes* (LAMARCK, 1822). LINNAEUS' taxon cannot be simply ignored, and the most appropriate specimens conforming to LINNAEUS' diagnosis and figure citations must be selected to serve as types of *Murex hippocastanum*. The following are here selected as types: Lectotype: length - 53.7 mm; width - 44.7 mm; height of aperture - 46.8 mm; this specimen has "Mur. B" written on the labrum and "545" on the columella. Paralectotype: length - 39.0 mm; width - 31.8 mm; height of aperture - 34.2 mm. These 2 specimens are conspecific with the *Purpura galeodes* LAMARCK, 1822. The third specimen (53.4 × 47.2 × 33.5 mm) is the species *Galeodes tuberosa* RÖDING, 1798, and should be excluded from the type series.

Thais armigera (LINK, 1807)

(Plate 47, Figure 2)

1807. *Mancinella armigera* LINK, Besch. Nat. Samml. Univ. Rostock, p. 115
1846. *Purpura affinis* REEVE, Conch. Icon., 3, pl. 13, sp. 77
1919. *Thais armigera* "CHEMNITZ", COOKE, Proc. Malacol. Soc. London, 13: 92, fig. 10 (radula)

Shell: Dirty-white in colour, occasionally ornamented with brown bands. Body whorl sculptured with 2 - 4 spiral rows of prominent somewhat spinose nodes, earlier whorls with a single row; interstices spirally corded. Aperture wide, white to yellowish in colour, edge of labial lip

flecked with brown, denticulate; columella white, irregularly banded with fawn or chocolate-brown, anteriorly with weak or prominent plicae.

L: 40 - 98.0 mm; W: 65 - 80%; HA: 56 - 61%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Thais intermedia (KIENER, 1835)

(Plate 47, Figure 3)

1835. *Purpura intermedia* KIENER, Spec. gén. icon. coq. viv., 7: 51; pl. 12, figs. 34, 34a

1919. *Thais hippocastanum* var. *intermedia* KIENER, COOKE, Proc. Malacol. Soc. London, 13: 95, fig. 4 (radula)

Shell: Similar in form, size and sculpture to *Thais aculeata* but differing in apertural features. The aperture is white, the edge of the labial lip has 4 - 5 squarish chocolate-brown blotches and 25 - 30 small and sharp exterior denticles; interior denticles white and round, numbering from 9 - 13.

L: 30 - 50 mm; W: 63 - 70%; HA: 57 - 64%

Type Locality: Les côtes du Sénégal, l'Océan des Grandes Indes, et la mer Pacifique.

Habitat: On reefs, under coral rocks, in shallow water. Moderately rare.

Distribution: North and West Viti Levu. - Indo-Pacific.

Mancinella LINK, 1807

Mancinella LINK, 1807, Besch. Nat. Samml. Univ. Rostock, 3te Abth., p. 115. Type species by *T. Murex mancinnella* LINNAEUS, 1758

Mancinella mancinnella (LINNAEUS, 1758)

(Plate 47, Figure 4; Text figure 1)

1758. *Murex mancinnella* LINNAEUS, Syst. Nat., ed. 10: p. 751

1798. *Volema alouina* RÖDING, Mus. Bolten., p. 58

1798. *Volema glacialis* RÖDING, Mus. Bolten., p. 58

1807. *Mancinella aculeata* LINK, Besch. Nat. Samml. Univ. Rostock, p. 115

1816. *Purpura gemmulata* LAMARCK, Tabl. Encycl. Méthod., p. 2; pl. 397, figs. 3a, 3b

1822. *Purpura mancinnella* LAMARCK, Anim. s. vert., 7: 239

Shell: Globose, yellowish to reddish orange in colour, irregularly flecked with white. Sculptured with 4 spiral rows of sharp or blunt spines and spiral cords. Aperture wide, labrum with orange lirae, columella smooth or irregularly plicate.

Radula: Odontophore 10.9 mm long and 0.24 mm wide in an individual with a shell 52.7 mm in length; rows

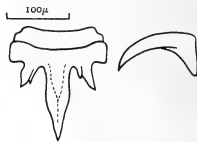


Figure 1

Mancinella mancinnella (LINNAEUS)

half row of radular teeth
Fiji Islands

of teeth number 159 (plus 13 nascentes). Rhachidian with a long central cusp, intermediate denticles lacking, side-cusps bifid, and laterals simple and curved.

L: 25 - 60 mm; W: 72 - 80%; HA: 65 - 73%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: E. A. SMITH (1913) in an article on *Murex mancinnella* LINNAEUS pointed out that the Linnaean taxon is a composite species, but failed to designate a type or restrict the usage of *M. mancinnella*. The Linnaean collection in London contains 3 specimens in a box for *M. mancinnella*, which were isolated by HANLEY when

Explanation of Plate 47

Figure 1: *Thais aculeata* (DESHAYES) × 0.75

Figure 2: *Thais armigera* (LINK) × 0.75

Figure 3: *Thais intermedia* (KIENER) × 1.0

Figure 4: *Mancinella mancinnella* (LINNAEUS) × 1.0

Figure 5: *Mancinella tuberosa* (RÖDING) × 1.0

Figure 6: *Drupa clathrata* (LAMARCK) × 1.2

Figure 7: *Drupa morum* RÖDING × 1.2

Figure 8: *Drupa ricinus* (LINNAEUS) - White form × 1.5

Figure 8a: *Drupa ricinus* (LINNAEUS) - Orange spotted form × 1.5

Figure 9: *Drupa marginata* (BLAINVILLE) × 1.0

Figure 10: *Drupa rubusidacus* RÖDING × 1.0

Figure 10a: *Drupa rubusidacus* RÖDING × 1.0

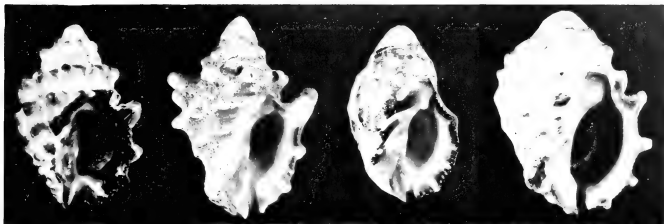


Figure 1

Figure 2

Figure 3

Figure 4



Figure 5

Figure 6

Figure 7

Figure 8

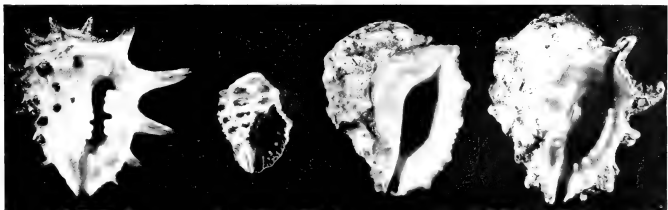


Figure 8 a

Figure 9

Figure 10

Figure 10 a



he examined the collection: 2 specimens are the species *Drupa cornus* RÖDING, 1798 and 1 specimen is the *Mancinella mancinella* of authors. LINNAEUS' original description applies only to the *M. mancinella* of authors, not to the *Drupa cornus* RÖDING. LINNAEUS described the aperture of *Murex mancinella* as toothless, but both specimens of *Drupa cornus* in the Linnaean collection have 5-6 prominent labial denticles. To preserve the usage of *Mancinella mancinella* of authors, the following specimen is designated here as the lectotype of *Murex mancinella* LINNAEUS: length - 41.6 mm; width - 30.9 mm; height of aperture - 27.7 mm; the shell has 16 orange labral lirae and represents the species *Mancinella mancinella* of authors.

The other two specimens ($43.2 \times 25.8 \times 22.4$ mm and $35.5 \times 23.9 \times 22.8$ mm) have the number "544" marked on the columella; on the larger specimen the number "762" has been obliterated. These 2 specimens are the *Drupa cornus* RÖDING and are excluded from the type series; they were either added by LINNAEUS after 1758 or were erroneously selected by HANLEY as types of *Murex mancinella*.

Mancinella tuberosa (RÖDING, 1798)

(Plate 47, Figure 5; Text figure 2)

1798. *Galeodes tuberosa* RÖDING, Mus. Bolten., p. 53, No. 679
 1798. *Drupa trapa* RÖDING, Mus. Bolten., p. 56, No. 709
 1798. *Vasum castaneum* RÖDING, Mus. Bolten., p. 57, No. 716
 1807. *Mancinella castanea* LINK, Besch. Nat. Samml. Univ. Rostock, 3te Abth., p. 115
 1832. *Purpura pica* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 213; pl. 9, fig. 9
 1907. *Purpura pica* var. *major* COUTURIER, Journ. Conchyl., 55: 142

Shell: Dirty white in colour, nodes flecked with brown. Sculptured with 2 rows of angulate nodes on the body whorl and smaller nodules towards the base; interstices spirally striate. Aperture wide, yellowish in colour, edge of labial lip with small and numerous denticles and blackish spots; the labrum has prominent orange lirae, the columella has small plicae anteriorly. Operculum has either an off-central or lateral nucleus.

Radula: Odontophore 15.6 mm long and 0.27 mm wide in an animal with a shell 49.5 mm in length; rows of teeth number 196 (plus 13 nascentes). Rhachidians with a long central cusp, intermediate denticles simple, outer cusps prominent; laterals simple.

L: 30-60 mm; **W:** 67-77%; **HA:** 63-73%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

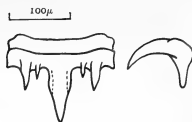


Figure 2

Mancinella tuberosa (RÖDING)
 Fiji Islands
 half row of radular teeth

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: *Mancinella tuberosa* is the type species of *Menathais* IREDALE, 1937. The radula of *Mancinella tuberosa* is basically similar to the radula of *M. mancinella*; both species have a lirate labrum. COOKE (1919) figured a radula of *M. mancinella* (as *Thais gemmulata*) which had a rhachidian with simple side-cusps and no intermediate denticles whatever, and *M. tuberosa* (as *Thais pica*) with rhachidians equipped with short intermediate denticles. It is obvious that the presence or absence of intermediate denticles is a variable character.

Drupa RÖDING, 1798

Drupa RÖDING, 1798, Mus. Bolten., p. 55. Type species by SD (ROVERETO, 1899) *D. morum* RÖDING, 1798

Discussion: SUTER (1913) is generally credited with the type species designation; however, ROVERETO's (1899) designation is an earlier one.

The radula of *Urosalpinx cinereus* (SAY, 1824), the type species of *Urosalpinx* STIMPSON, 1865, as figured by STIMPSON (1865), does not differ in basic features from the radula of the *Drupa* group. It is suggested that *Urosalpinx*, on the basis of shell and radula characters, would be more properly placed in the Thaidinae than in the Tritonaliinae.

HERTLEIN (1960) differentiates *Drupa* RÖDING from *Morula* SCHUMACHER by the feature of grouped and ungrouped labial denticles respectively. This feature is not constant, as both types of denticles can occur in the same species.

The radula of *Drupa* species differs from those of *Morula* in one essential characteristic: the side-denticles of the rhachidians in *Drupa* are bifid to quadrid, but are always simple in *Morula* and the subgenus *Cronia* H. & A. ADAMS.

For a discussion on *Canrena* LINK, 1807, see under *Drupa morum* RÖDING.

Drupa clathrata (LAMARCK, 1816)

(Plate 47, Figure 6)

1816. *Ricinus clathrata* LAMARCK, Tabl. Encycl. Méth., p. 2; pl. 395, figs. 5a, 5b
 1828. *Murex hystrix* WOOD, Ind. Test., pl. 26, fig. 50 (non LINNAEUS, 1758)
 1936. *Drupa rubuscaesia* BOLTEN-RÖDING, Hirase, Col. Jap. shells, p. 79; pl. 110, fig. 10 (non *D. rubuscaesius* RÖDING, 1798)
 1951. *Drupa rubuscaesius* RÖDING, Hirase & TAKI, Handb. illust. shells col., pl. 110, fig. 10 (non RÖDING, 1798)
 1959. *Drupa rubuscaesium* RÖDING, 1798, Kira, Col. Ill. shells Japan, 1: 58; pl. 23, fig. 9 (non *D. rubuscaesius* RÖDING, 1798)

Shell: Light fawn to yellowish in colour, window-like interstices dark brown. Sculptured with about 6 spiral rows of spinose nodules on the body whorl, earlier whorls with a single row; interstices spirally corded. Edge of labial lip orange-brown, ornamented with bifid or trifid denticles; columella violet posteriorly, plicae white, interstices orange-brown. Operculum moderately thin, orange-brown in colour and with a lateral nucleus.

L: 25 - 35 mm; W: 80 - 87%; HA: 72 - 86%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Moderately rare.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: HEDLEY (1913) initiated the erroneous assumption that *Drupa clathrata* is synonymous with *D. rubuscaesius*, and several authors have adopted this taxonomic treatment. RÖDING referred to MARTINI (1777), plate 102, figures 976 and 977 for his species; the figures cited are a convincing likeness of the orange-flecked form of *Drupa ricinus* (LINNAEUS).

Drupa marginatra (BLAINVILLE, 1832)

(Plate 47, Figure 9; Text figure 3)

1832. *Purpura marginatra* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat. 1: 218; pl. 10, fig. 1
 1853. *Purpura infumata* HOMBRON & JAQUINOT, Voy. Pole Sud Ast. & Zélée, Atlas, pl. 22, figs. 13, 14
 1854. *Purpura infumata* HOMBRON & JAQUINOT, Voy. Pole Sud Ast. & Zélée, text, p. 85 (emend.)
 1862. *Ricinus fusca* KÜSTER, Conch. Cab. 2nd ed., 3: 26; pl. 4, fig. 16
 1862. *Sistrum affine* PEASE, Proc. Zool. Soc. London, p. 244
 1871. *Purpura (Sistrum) fusco-nigra* DUNKER, Malak. Blätter, 18: 154

1901. *Sistrum indigoferum* MELVILL, Ann. Mag. Nat. Hist., 7: 551; pl. 9, fig. 1

Shell: Dirty grey to dark brown in colour; sculptured with coarse and blunt nodules, interstices of nodules either grooved or scaly. Aperture wide, dark chocolate to purplish-brown; labial lip with 4 - 5 denticles, columella with obsolete plicae. The interior of the aperture either bluish-white, violet, or brownish-purple, and lirate. Periostracum thick, brown in colour.

Radula: Odontophore 3.1 mm long, 0.14 mm wide in an animal with a shell 17.8 mm long; rows of teeth number 171 (plus 9 nascentes). The central cusp of the rachidian is simple, intermediate denticles are absent and the



Figure 3

Drupa marginatra (BLAINVILLE)

Fiji Islands
half row of radular teeth

side cusps are trifid. Side-denticles number from 4 to 6.

L: 14 - 26 mm; W: 69 - 75% HA: 67 - 75%

Type Locality: Iles Samoa.

Habitat: Under basalt rocks, near the high tide level. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Drupa morum RÖDING, 1798

(Plate 47, Figure 7; Text figure 4)

1798. *Drupa morum* RÖDING, Mus. Bolten., p. 55, No. 694
 1807. *Canrena neritoidea* LAMARCK, Besch. Nat. Samml. Univ. Rostock, 3te Abth., p. 126 (restricted to MARTINI, 1777, 3, pl. 101, figs. 972, 973)
 1816. *Ricinus horrida* LAMARCK, Tabl. Encycl. Méth., p. 1; pl. 395, figs. 1a, 1b
 1817. *Ricinus violacea* SCHUMACHER, Ess. nouv. syst., p. 240

Shell: Creamy-white in colour, ornamented with dark brown nodes. Sculptured with 5 - 6 spiral rows of nodules on the body whorl and a single row on earlier whorls; interstices spirally lirate. Aperture constricted, light or dark violet, labial lip with 2 groups of multiple denticles and 2 single denticles, columella plicate anteriorly. Operculum dark brown with a lateral nucleus.

Radula: Odontophore 11.0 mm long and 0.19 mm wide in an animal with a shell 39.3 mm in length; rows of

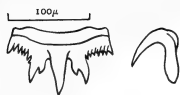


Figure 4

Drupa morum RÖDING

Fiji Islands

half row of radular teeth

teeth number 275 (plus 16 nascentes). Rhachidian with a simple central cusp, prominent bifid or trifid side-cusps and 5-7 side-denticles.

L: 25-42 mm; W: 82-94%; HA: 80-90%

Type Locality: None.

Habitat: In crevices of reefs and under coral rocks, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: On the basis of LINK's (1807) cited references, his *Canrena neritoidea* is a composite species. The cited figures from MARTINI (1777, pl. 101, figs. 972, 973) represent the species *Drupa morum* RÖDING, and have also been cited by RÖDING (1798) for his species; the other cited figures from MARTINI (pl. 102, figs. 976 to 979) are *Drupa grossularia* RÖDING, 1798 (figs. 978, 979 only). To prevent *Canrena* LINK, 1807, being utilized as an earlier name for *Drupina* DALL, 1923, figures 972 and 973 on plate 101 in MARTINI (1777) are here designated as the lectotype representatives of *Canrena neritoidea* LINK. *Canrena neritoidea* is the type species of *Canrena* LINK by monotypy, and thus becomes an objective synonym of *Drupa* RÖDING.

Drupa ricinus (LINNAEUS, 1758)

(Plate 47, Figures 8, 8a; Text figures 5, 6)

1758. *Murex ricinus* LINNAEUS, Syst. Nat., ed. 10, p. 750, No. 464 (orange-spotted form and white form)

1758. *Murex hystrix* LINNAEUS, Syst. Nat., ed. 10, p. 750, no. 468 (? specim. juv.)

1798. *Drupa tribulus* RÖDING, Mus. Bolten., p. 55, No. 695

1798. *Drupa rubuscaesius* RÖDING, Mus. Bolten., p. 55, No. 696 (orange-spotted form)

1816. *Ricinus arachnoides* LAMARCK, Tabl. Encycl. Méth., p. 1; pl. 395, figs. 3a, 3b (orange-spotted form)

1832. *Purpura albo-labris* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 208; pl. 9, fig. 5 (white form)

Shell: White in colour, nodules dark brown. Generally sculptured with 5 spiral rows of blunt or spinose brown nodules, earlier whorls with a single row; interstices spirally lirate. Aperture narrow, and either pure white or flecked with orange; the orange flecks are situated op-

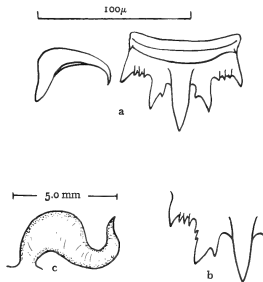


Figure 5

Drupa ricinus (LINNAEUS) - white form

Fiji Islands

a. half row of radular teeth

b. part of rhachidian showing variation of cusps

c. penis

posite the nodules on the labial lip, one pair of flecks borders the anal canal and a single orange streak is situated on the columellar side of the siphonal canal. Labial denticles are generally grouped, the columella is prominently plicate.

Radula: Odontophore 6.2 mm long and 0.11 mm wide in an animal with a shell 25.0 mm in length; rows of teeth number 204 (plus 19 nascentes). Rhachidian with a simple central cusp, side-cusps long or short, bifid to quadrid, side denticles number from 2-3; laterals are simple.

L: 18-32 mm; W: 84-107%; HA: 82-94%

Type Locality: O. Asiatic.

Habitat: In crevices of coral rocks, on algae-matted reef platforms, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: Authors usually separate the form with a pure white aperture as *Drupa albolabris* (BLAINVILLE) and the form with an orange-flecked aperture as *D. arachnoides*

(LAMARCK). The Linnaean type-series of *Murex ricinus* consists of 3 specimens: 1 specimen is the form with the white aperture, another specimen is the orange-spotted form and the third specimen is juvenile. Linnaeus' speci-

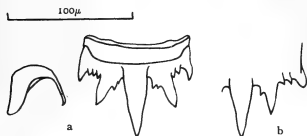


Figure 6

Drupa ricinus (LINNAEUS) - orange spotted form

Fiji Islands

a. half row of radular teeth

b. part of rhachidian showing variation of cusps

fic name is therefore applicable to either form.

The specific validity of the 2 forms has been open to question, and a more detailed study of this common species was indicated. In the notes which follow, the form with a pure white aperture will be referred to as the "white form;" and the form with orange flecks as the "orange-spotted form."

Seven localities right around Viti Levu, a circumference of approximately 320 miles, were sampled, and these will be referred to as stations A to G.

Station A: Nananu-i-Ra Island, off the North coast of Viti Levu: Both forms occur in about equal numbers and share the same habitat.

Station B: Islands of the Mamanuca group: Both forms occur in about equal numbers and share the same habitat.

Station C: Manava Island, off the coast of Northwest Viti Levu: the orange-spotted form is rather more numerous than the white form, but they share the same habitat.

Station D: Nadroga reef, extending from Cuvu to Korolevu, a distance of approximately 40 miles: Both

forms are represented in about equal numbers and share the same habitat.

Station E: Namagumagua village, South Viti Levu: Collecting in January 1968 produced only the orange-spotted form and not a single specimen of the white form; however, 10 miles further west and one day later, both forms were found on the same reef, under the same conditions.

Station F: Rat-Tail Passage, main Suva reef: Here the orange-spotted form was more numerous than the white form, but both shared the same habitat.

Station G: Viti Levu Bay, Northeast of Viti Levu: Both forms occur in about the same numbers and share the same habitat.

Habitat: Both forms of the species are rare in muddy-sand localities of Northern Viti Levu coastal reefs; the species is more common in clean coral sand localities of Southern coastal reefs. The species occurs in great numbers on algae-matted reef platforms and is more frequent towards the reef-edge. It also lives in cracks and crevices of reefs without algal matting and is also found on the underside of coral rocks. Both forms may be found on the same reef only a few feet apart or under the same coral rock.

Shell Morphology: Apart from the different colouring of the aperture, there is no single diagnostic character which would separate the species; in beach-worn condition the 2 forms cannot be separated.

The majority of specimens of the orange-spotted form generally have 7 orange spots which are arranged as follows: 2 spots border the anal canal (1 on each side), 1 spot is situated opposite the first quadrid group of labial denticles, another spot opposite the bifid labial denticle, and a spot each is situated opposite the single anterior denticles; 1 spot is placed on the columellar side of the siphonal canal. Occasional specimens show an orange line on the edge of the columella.

Specimens have been collected which are obvious intergrades between the 2 colour-forms: specimens with a pure white aperture, apart from a thin orange line on the labial lip; specimens with either 1 or 2 single orange spots near the anal canal, and specimens with a single orange spot on the labial lip.

Radula: No constant difference could be observed in ei-

Explanation of Plate 48

- Figure 11: *Drupina grossularia* (RÖDING) $\times 1.5$
 Figure 12: *Drupella cornus* (RÖDING) - Female $\times 1.5$
 Figures 12a, 12b: *Drupella cornus* (RÖDING) - Males $\times 1.75$
 Figure 13: *Morula biconica* (BLAINVILLE) $\times 2.0$
 Figures 14, 14a: *Drupella ochrostoma* (BLAINVILLE) $\times 2.0$

- Figures 15, 15a: *Drupella rugosa* (BORN) $\times 1.75$
 Figure 16: *Drupella* cf. *D. angulata* (REEVE) $\times 2.25$
 Figures 16a, 16b: *Drupella* cf. *D. angulata* (REEVE) $\times 2.25$
 Figures 17, 17a: *Morula anaxeres* (KIENER) $\times 2.0$
 Figure 18: *Morula biconica* (BLAINVILLE) $\times 2.0$

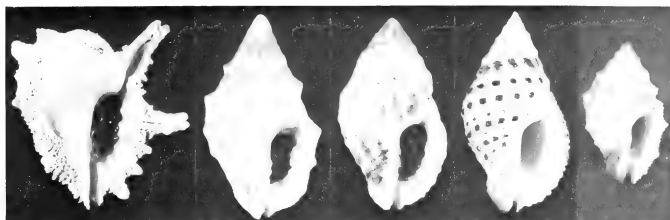


Figure 11

Figure 12

Figure 12 a

Figure 12 b

Figure 13

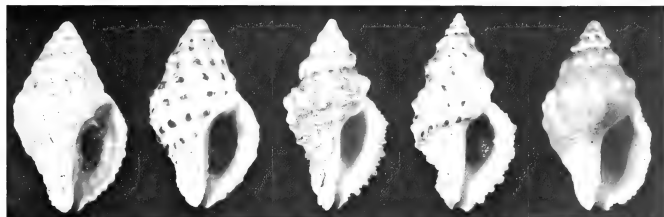


Figure 14

Figure 14 a

Figure 15

Figure 15 a

Figure 16



Figure 16 a

Figure 16 b

Figure 17

Figure 17 a

Figure 18



ther the pattern of the rhachidians or laterals, nor in the ratio of length : width of the odontophore or in the occurrence of either bifid, trifid, or quadrid side-cusps. Wu (1965) was unable to find any constant differences in the radula of both forms, but pointed out that one form had more numerous side-denticles than the other; this feature I found extremely variable in both forms (see Text figures).

Sexual Dimorphism of the Shell: None was observed; the white and orange-spotted forms occur in both males and females.

Sexual Dimorphism of the Radula: None was observed; variations which do exist are erratic in both males and females of both forms.

Penis: The muriciform penis is common to both colour forms and is appreciably different from the tubular penis of *Drupella* THIELE.

Stomach Pouch: This was found to be either orange-red or brown in both colour forms of both sexes.

Gut Content: Same in both forms, consisting of coral fragments, sponge spicules and algal matter.

Living Animal: The short, stubby tentacles may be either plain brownish-fawn or may have an additional blackish-brown transverse band on the tentacles in either form.

Both forms have been reported from widely-scattered Indo-Pacific localities. HERTLEIN (1960) reports both colour forms from the Galápagos and Clipperton Islands.

Evidence on hand strongly suggests that the two forms are conspecific. The occurrence of 2 colour forms in a species is by no means confined to *Drupa ricinus*, but can be observed in *Strombus gibberulus gibbosus* (RÖDING, 1798), *Duplicaria duplicata* (LINNAEUS, 1758), and *Conus marmoreus* LINNAEUS, 1758, and several other gastropods. This once again confirms the futility of using shell-colour as a guide for specific diagnosis of molluscs.

Drupa rubusidaeus RÖDING, 1798

(Plate 47, Figures 10, 10 a)

1798. *Drupa rubusidaeus* RÖDING, Mus. Boltzen., p. 55, No. 698
 1807. *Mancinella hystrix* LINK, Besch. Nat. Samml. Univ. Rostock, p. 115
 1822. *Ricinuia miticula* LAMARCK, Anim. s. vert., 7: 231
 1828. *Murex hippocastanum* WOOD, Ind. Test., pl. 26, fig. 53
 (non *Murex hippocastanum* LINNAEUS, 1758)
 1832. *Purpura spathulifera* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 212; pl. 9, fig. 8
 1862. *Ricinuia reeveana* CROSSE, Journ. Conchyl. 10: 47; pl. 1, fig. 3

Shell: Yellowish in colour, generally heavily encrusted with coral growth. Sculptured with 4-6 spiral rows of

bluntly spinose nodes, earlier whorls with a single row. Edge of aperture yellow or orange, labial lip rose-violet and ornamented with 7-9 denticles which may extend into the aperture and become whitish within. Columella rose-violet in colour, irregularly flecked with yellow or orange, and sculptured with plicae anteriorly; the edge of the columellar callus occasionally has 6-7 small denticles. Operculum moderately thin, orange-brown in colour and with lateral nucleus.

L: 25-58 mm; W: 78-94%; HA 76-87%

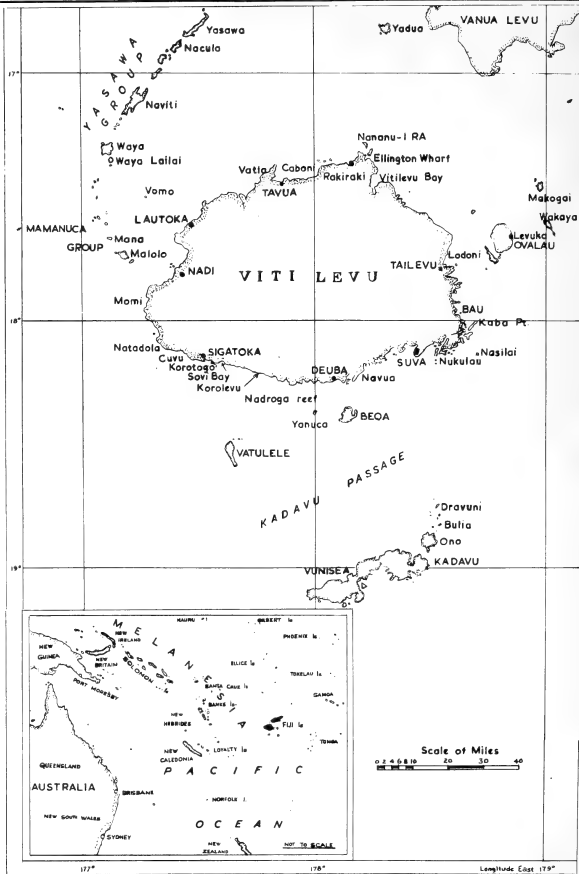
Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: The species *Drupa rubusidaeus* has a confused nomenclature, and RÖDING's specific name has occasionally been applied to the species *Drupa clathrata* (LAMARCK). The confusion probably started with HEDLEY (1913) who placed *Ricinuia clathrata* LAMARCK, *R. speciosa* DUNKER, 1867 and *Purpura spathulifera* BLAINVILLE in the synonymy of *Drupa rubusidaeus* RÖDING; several Japanese workers subsequently adopted HEDLEY's synonymy. The identification of *D. rubusidaeus* depends on the interpretation of RÖDING's (1798) cited figures from MARTINI (1777, 3: 283, pl. 101, figs. 974, 975). It has to be admitted that the cited figures are somewhat ambiguous, and could represent in part either *D. clathrata* (LAMARCK) or *D. rubusidaeus* RÖDING. The general form, numerous spines, and shape of the juncture of the aperture would favour *D. clathrata*, but the colouring and general aspect of the apertural features strongly favour *D. rubusidaeus*. MARTINI (*op. cit.*) called his species "Der Igel," and referred to GUALTIERI (1742), pl. 28, fig. N as a reference; it is unfortunate that these figures represent the species *D. ricinus* (LINNAEUS). No denticles are visible in the MARTINI figures of *D. rubusidaeus*, but they are mentioned by MARTINI in the description. Although ambiguous, the figures tend to represent the same species as the *Purpura spathulifera* BLAINVILLE, and RÖDING's earlier name has been accepted in this paper.

DUNKER (1867) described a *Ricinuia speciosa* (non *Purpura speciosa* VALENCIENNES, 1832), but in 1870 (p. 139) he stated that his *R. speciosa* is a smaller and mature example of *R. reeveana* CROSSE. The United States National Museum collection has numerous specimens of *Drupa speciosa* from Polynesia, and it is evident that this is a valid species confined to Polynesia, and intermediate in characters between *D. clathrata* and *D. rubusidaeus*. EMERSON in WEAVER (1966) reported the species from the Fiji Islands, but it does not occur there. Oos-



TINGH (1931) reports *D. hystrix* var. *speciosa* DUNKER from Sumatra, but this record needs clarification.

The types of *Ricinula miticula* LAMARCK are in the Muséum d'Histoire Naturelle in Geneva; the holotype measures 26.3 mm, the paratype 26.0 mm; they are the species *Drupa rubusidaeus* RÖDING. The holotype of *Ricinula reeveana* CROSSE is in the British Museum (Natural History) in London; it measures 48.2 × 38.8 mm; this species which was described from Nouhiva (= Nukuhiva), Marquesas, is not conspecific with *D. speciosa* (DUNKER), but is a large, immature example of *D. rubusidaeus* RÖDING with a bright maroon coloured aperture.

Drupina DALL, 1923

Drupina DALL, 1923, Proc. Acad. Nat. Sci. Phila., 75: 303.

Type species by OD *Ricinula digitata* LAMARCK, 1816
= *Drupa grossularia* RÖDING, 1798

Discussion: The shell of *Drupina* is similar to that of *Drupa* RÖDING, but the sculpture is more scabrous and minutely foliated, labial teeth are smaller and grouped, although they may be paired, and the columella is heavily calloused. The labial digitations are extended.

The radular pattern of *Drupina* differs appreciably from any known radula of other thaidine genera, and fully supports DALL's generic separation on morphological features of the shell. The genus is at the present time monotypic and contains an Indo-Pacific species.

Drupina grossularia (RÖDING, 1798)

(Plate 48, Figure 11; Text figure 7)

- 1798. *Drupa grossularia* RÖDING, Mus. Bolten., p. 55, No. 700
- 1816. *Ricinula digitata* LAMARCK, Tabl. Encycl. Méth., p. 2; pl. 395, figs. 7a, 7b
- 1817. *Ricinella dactyloides* SCHUMACHER, Ess. nouv. syst., p. 241
- 1828. *Murex ricinus* WOOD, Ind. Test., pl. 26, fig. 51 (non LINNAEUS, 1758)
- 1832. *Purpura lobata* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 210; pl. 9, fig. 7 (Indian Ocean subspecies)
- 1850. *Purpura laurentiana* PETIT DE LA SAUSSAYE, Journ. Conchyl., 1: 403; pl. 13, fig. 2 (specim. juv.)
- 1965. *Drupina glossularia* (RÖDING), Wu, Bull. Inst. Zool. Acad. Sin., 4: 99 (invalid emendation)
- 1967. *Drupina glossularia* (LINNÉ), HARE & KOSUGE, Std. Book Japan. shells col., p. 70; pl. 27, fig. 22

Shell: Uniformly creamy-white to yellow in colour. Sculptured with about 5 heavy spiral cords and intermediate scabrous lirae on the body whorl, and a single row of obsolete and indistinct nodules. Aperture narrow, orange in colour, edge of labial lip with 5 digitations which are

actual extensions of the spiral cords; the labial lip has prominent white nodules and the columella is heavily calloused and plicate; the edge of the labial callus is sometimes finely denticulate. Operculum brown in colour, with a lateral nucleus.

Radula: Odontophore 6.5 mm long and 0.14 mm wide in an animal with a shell 30.3 mm in length; rows of teeth

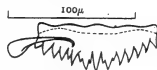


Figure 7

Drupina grossularia (RÖDING)

Fiji Islands

half row of radular teeth

number 271 (plus 17 nascentes). The rhachidian is equipped with about 13 moderately short cusps of almost uniform size, the side-cusps are trifid; laterals small and simple.

L: 22-36 mm; W: 96-113%; HA: 85-91%

Type Locality: None.

Habitat: On reefs, near reef's edge, in crevices and under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Pacific.

Discussion: *Drupina lobata* (BLAINVILLE, 1832) is a subspecies or colour form of *D. grossularia* with a dark brown-maroon aperture, and appears to be restricted to the Indian Ocean.

Drupella THIELE, 1925

Drupella THIELE, 1925, Wissensch. Erg. Exp. Valdivia, 17: 171.

Type species by SD (THIELE, 1929) *Drupa* (*Drupella*) *ochrostoma* (BLAINVILLE, 1832) = *Purpura ochrostoma* BLAINVILLE, 1832

Discussion: In shell features, species of *Drupella* resemble *Morula* SCHUMACHER, 1817 and *Cronia* H. & A. ADAMS, 1853, or even some species of *Maculotriton* DALL, 1904. They are a small compact group whose radula bears no similarity to any other muricid genus, with the possible exception of *Vexilla* SWAINSON, 1840. Species of *Vexilla* also have a plain or serrated rhachidian; the laterals, although not as long as those of *Drupella*, are more elongate than the typical muricid lateral, and are also either simple or denticulate (see COOKE, 1919, and THIELE, 1929). The penis also differs in structure

from that of *Drupa* s. str.; it is stout, stubby and tubular, and has a large oval seminal duct exit.

Species of *Drupella* are widely distributed in the Indo-West Pacific. They inhabit a variety of habitats and are not confined to branching coral (fide COOKE, 1895 and DEMOND, 1957); they may be found in branching coral, in crevices of algae-matted reef platforms and on the underside of coral blocks which litter Fiji reefs, and occur on coastal reefs as well as outlying islets.

Drupella cornus (RÖDING, 1798)

(Plate 48, Figures 12, 12a, 12b; Text figure 8)

1798. *Drupa cornus* RÖDING, Mus. Bolten., p. 56, No. 704 (female form)
 1832. *Purpura nassoides* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 205 (male form)
 1832. *Purpura elata* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat. 1: 207; pl. 11, fig. 1 (female form)
 1833. *Purpura nassoides* QUOY & GAIMARD, Voy. *Astrolabe*, Zool., 2: 564; pl. 38, figs. 7, 8, 9 (male form)
 1839. *Purpura* (*Ricinula*) *martiniana* ANTON, Verz. Conch., p. 88
 1846. *Ricinula spectrum* REEVE, Conch. Icon., 3, pl. 3, sp. 19 (female form)
 1846. *Ricinula dealbata* REEVE, Conch. Icon., 3, pl. 4, sp. 26
 1852. *Ricinula eburnea* KÜSTER, Conch. Cab., 2nd ed., 3: 17; pl. 3, fig. 9
 1853. *Purpura alba* HOMBRON & JAQUINOT, Voy. Pole Sud Ast. & Zélee, Atlas, pl. 22, figs. 30, 31 (specim. juv.)
 1918. *Drupa vitiensis* PILSBRY & BRYAN, Nautilus 31, pl. 9, fig. 5 (dark noded male form)
 1921. *Sistrum vitiense* PILSBRY, Proc. Acad. Nat. Sci. Phila., 72: 319
 1967. *Drupella manilla* [sic] LINNÉ, HABE & KOSUGE, Std. Book Japan. shell, p. 70; pl. 27, fig. 20 (female form)
 1967. *Drupa* (*Drupella*) *chaidaea* (DUCLOS), ORR-MAES, Proc. Acad. Nat. Sci. Phila., 119: 129; pl. 11, fig. 6 (male form)

Shell (Female): White in colour throughout. Sculptured with 4 spiral rows of prominent and pointed nodes, earlier whorls with a single row; interstices of nodules with 3-5 spiral grooves. Aperture narrow, porcellaneous white, labial lip with from 5-8 moderately sized denticles,

lower half of columella with 2-5 irregular short plicae. Anal notch indistinct, base with a heavy callus.

Shell (Male): Generally smaller than that of females, but rare specimens may attain the same size. The shell is more bulbous in appearance and the sculpture is appreciably more discrete. The spiral nodules are more numerous, smaller and blunter, and the shell is spirally corded, not grooved; the aperture appears wider and labial denticles smaller.

Radula: Odontophore brown in colour, 8.0 mm long and 0.28 mm wide in an animal with a shell 38.0 mm in length; rows of teeth number 264 (plus 33 nascentes). Rhachidian with a massive central cusp, moderately smaller outer cusps, thin and sharp intermediate denticles and 8-13 serrated denticles at either side of the central cusp; laterals are long and thin, ca. 6 times as broad as the rhachidian, sharply and minutely denticulate at the base, distal end curved and pointed, and either simple or bifid.

Eighteen specimens from various Fijian localities were examined and no sexual dimorphism of the radula was evident. Both males and females had the same type of rhachidian; the curved distal end of the laterals was simple in most specimens, bifid in others, and 1 male specimen 22.3 mm in length showed both simple and bifid tips on laterals in the same ribbon.

The inner part of the base of the lateral teeth is obviously also used in abrading food particles; in the first one dozen or more rows of teeth, the inner denticles were completely worn off and came back to normal size as the rows progressed towards the end with the nascentes.

L: 18-50 mm; W: 51-61%; HA: 48-57%

Type Locality: None.

Habitat: On reefs in crevices and under coral rocks, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific. **Discussion:** ARAKAWA (1958) figured the radulae of *Drupella cornus* (RÖDING) and *D. fragum* (BLAINVILLE), and reported on the sexual dimorphism of the radula in the two species. His text figures 1 and 2 of *D. fragum* are both immature specimens of *D. cornus*; the rhachidians and laterals of the radula of *D. cornus* depicted by ARA-

Explanation of Plate 49

- Figure 19: *Morula granulata* (DUCLOS) × 2.0
 Figure 20: *Morula nodicostata* (PEASE) × 3.0
 Figure 21: *Morula parva* (REEVE) × 3.2
 Figures 22, 22a: *Morula spinosa* (H. & A. ADAMS) × 1.2
 Figures 23, 23a: *Morula uva* (RÖDING) × 1.5
 Figure 28: *Vexilla vexillum* (GMELIN) × 1.3
 Figure 29: *Nassa sarta* (BRUGUÈRE) × 1.0

- Figure 24: *Morula* (*Cronia*) *aurantiaca* (HOMBRON & JAQUINOT) × 1.5
 Figure 25: *Morula* (*Cronia*) *fiscella* (GMELIN) × 1.2
 Figure 26: *Morula* (*Cronia*) *margaritcola* (BRODERIP) × 1.5
 Figure 27: *Maculotrion egregius* (REEVE) × 1.5

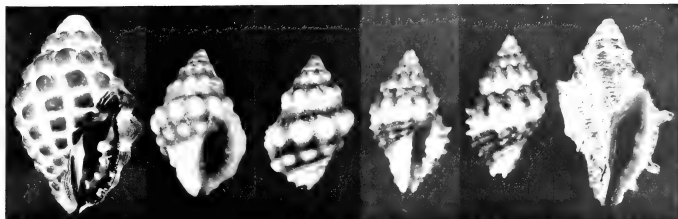


Figure 19

Figure 20

Figure 21

Figure 22



Figure 22 a

Figure 23

Figure 23 a

Figure 24



Figure 25

Figure 26

Figure 27

Figure 28

Figure 29



KAWA on plate 6, figures 5 and 12 fully agree with the radula of *D. cornus* from the Fiji Islands. In the 8 males and 10 females of *D. cornus* from Fiji waters examined, no difference in the pattern of rhachidians between the sexes was observed; a sexual dimorphism in the shell, however, was evident. In the juvenile stage (thin labial lip devoid of denticles) the shells of both sexes are the same, i. e., they are barrel-shaped with blunt small nodules and distinct spiral cords. In fully mature specimens, however, all the females examined had a heavy and large shell with prominent and spinose nodes, while all adult males retained the barrel-shaped form with blunt nodules and prominent spiral lirae. Both forms occurred in small colonies under the same rock and were observed in mating position.

The reed-like laterals of *Drupella cornus* are always serrated for a short distance at the base, whereas they are smooth in *D. rugosa* (BORN, 1778) and *D. ochrostoma* (BLAINVILLE, 1832). No side-denticles on the rhachidians

of *D. rugosa* (= *D. fragum* of ARAKAWA) were observed in any of the specimens examined. The distal end of the laterals may, as pointed out by ARAKAWA (*op. cit.*) be either bifid or simple. In view of the discrepancies between ARAKAWA's and my own findings, it is suspected that the differences in radula pattern are either regional or a third similar species may be involved.

The male form of *Drupella cornus* has been occasionally listed as *Purpura chaidea* DUCLOS, 1832. DUCLOS' species, however, is a nassarid-shaped species with prominent and thick axial folds which are decussated by close-set spiral striae.

The species *Ricinuia siderea* REEVE, 1846, is generally placed in the synonymy of *Drupella cornus* (RÖDING). REEVE's 3 syntypes are in the British Museum (Natural History), London, and from examination of the types it is evident that REEVE's *Ricinuia siderea* is a columbellid species and not a muricid; the holotype measures 12.8 by 6.4 mm.

Drupella ochrostoma (BLAINVILLE, 1832)

(Plate 48, Figures 14, 14a; Text figure 9)

1832. *Purpura ochrostoma* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 205

1833. *Purpura nasoides* var. QUOY & GAIMARD, Voy. *Astrolabe*, Zool., 2: 564; pl. 38, figs. 10, 11 (non BLAINVILLE, 1832)

Shell: Whitish to creamy-yellow in colour, nodules occasionally brown. Sculptured with 4 spiral rows of small, blunt and often brownish nodules (ca. 9-12 per row) which decrease in size towards the base; the penultimate whorl with a single or rarely double row of nodules. Interstices sculptured with 2 regular and scabrous spiral cords. Aperture orange, labial lip with 5-6 prominent white denticles; siphonal canal short and calloused.

Radula: Odontophore 7.0 mm long and 0.15 mm wide in

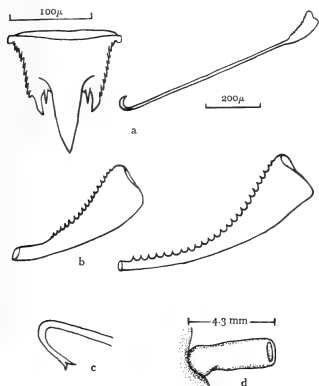


Figure 8

Drupella cornus (RÖDING)

Fiji Islands

- a. half row of radular teeth
- b. basal portion of lateral teeth - enlarged
- c. distal end of lateral teeth - enlarged
- d. penis



Figure 9

Drupella ochrostoma (BLAINVILLE)

Fiji Islands

half row of radular teeth

an animal with a shell 22.5 mm in length; rows of teeth number 205 (plus 26 nascentes) and early rows are worn. Rhachidians with a massive central cusp, thick outer cusps and small intermediate denticles; laterals long, slender and simple, curved at the distal end, and approximately 9 times as broad as the rhachidians.

L: 17-25 mm; W: 58-60%; HA: 56-63%

Type Locality: Tonga.

Habitat: On reefs, in crevices and under coral rocks, in shallow water. Uncommon.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: BLAINVILLE's (1832) reference to figure 8 is possibly an error for figure 10, which depicts a specimen with an orange aperture. Figures 7-9 are *Purpura nassoides* BLAINVILLE, 1832.

Drupella rugosa (BORN, 1778)

(Plate 48, Figures 15, 15a; Text figure 10)

1778. *Murex rugosus* BORN, Ind. rer. nat. Caes. Vindob., p. 303

1822. *Murex concatenatus* LAMARCK, Anim. s. vert., 7: 176

1832. *Purpura fragum* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 203; pl. 9, fig. 4

Shell: White in colour, rarely creamy-yellow, nodules occasionally dark brown. Sculptured with 3-4 spiral rows of prominent nodules, penultimate whorl with a single row; nodules are connected by scabrous spiral cords, and interstices are ornamented with 3-5 spiral ridges, base of shell with 2-3 heavy cords; some specimens show a distinct varix on the body whorl. Aperture white, labial lip with 6-10 denticles which are uniformly spaced, lower half of columella with 3-4 short plicae; siphonal canal short, stained with orange anteriorly.

Young specimens are scabrous, dark orange in colour with the nodules dark brown; penultimate whorl carries 2 rows of nodules which in the adult stage fuse into a single row; interstitial spiral cords very weak.

Radula: Odontophore brown in colour, 8.7 mm long and 0.23 mm wide in an animal with a shell 23.0 mm in length; rows of teeth number 166 (plus 21 nascentes). Rhachidians with a massive central cusp, prominent outer cusps and with or without an intermediate denticle. Laterals long and about 8 times as broad as the rhachidians, simple and curved at the distal end.

L: 20-35 mm; W: 52-56%; HA: 55-60%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Uncommon.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: BORN (1778) cited a figure from CHEMNITZ (1780, pl. 124, figs. 1155, 1156) for his species, which is a rather indifferently executed figure for the species un-

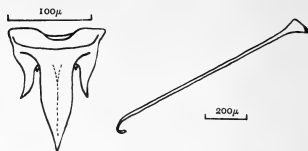


Figure 10

Drupella rugosa (BORN)

Fiji Islands
half row of radular teeth

der discussion; LAMARCK's *Murex concatenatus* was based on the same CHEMNITZ figure. In addition, LAMARCK (1822) cited LISTER (1685-92, pl. 954, fig. 5) which is *Morula uva* (RÖDING, 1798), while the reference to KNORR (1769, pl. 26, fig. 2) could just about represent any similar species. BLAINVILLE (1832) described his *Purpura fragum* as yellowish-white on the outside, with dark rose nodules and a completely white aperture. Fiji specimens agree with BLAINVILLE's diagnosis of a white aperture, but specimens with a yellowish-orange aperture do occur in other Pacific localities.

The shells of *Drupella cornus* and *D. rugosa* may appear similar when both are adult and heavily encrusted with coral growth; juvenile shells of both species, however, differ quite prominently.

The species *Drupella rugosa* from Fiji has a different radula pattern than has been figured by ARAKAWA (1958, as *D. fragum*), and no sexual dimorphism of the radula has been observed in this species.

Drupella c.f. *D. angulata* (REEVE, 1844)

(Plate 48, Figures 16, 16a, 16b; Text figure 11)

1844. *Triton angulatus* REEVE, Conch. Icon., 2, pl. 9, sp. 88

Shell: Small and moderately slender, variable in colour, but generally white or yellow, occasionally ornamented with spiral rows of black spots or orange-brown transverse zones. Whorls number from 5-6, and protoconch is not distinguishable in adult specimens. Body whorl sculptured with 1-3 rows of prominent or feeble and blunt nodules, while the penultimate whorl has either a single row of nodules or from 10-13 angulate and nodulose axial ribs; body whorl has an additional 12-20 moderately coarse spiral cords which may override the nodules. Aperture white, labial lip ornamented with 5-6

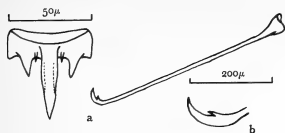


Figure 11

Drupella cf. *D. angulata* (REEVE)
Fiji Islands
a. half row of radular teeth
b. distal end of lateral tooth

small denticles, columella smooth; anterior canal short and open, anal canal prominent and almost resembling a daphnelloid notch.

Radula: Odontophore 4.6 mm long and 0.12 mm wide in an animal with a shell 12.5 mm in length; rows of teeth number 120 (plus 8 nascentes) and early rows are worn. Rhachidians with a long and slender central cusp, intermediate denticles small but slender, side cusps broad; laterals long and slender, 10 times as broad as the rhachidians, the distal end terminates in a simple curved cusp which has at the base a smaller accessory cusp.

L: 9-20 mm; W: 49-58%; HA: 52-60%

Distribution: Throughout the Fiji Islands. - ?

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Discussion: This species, although moderately common in Fiji, is not represented in the rather comprehensive molluscan collections of the U. S. National Museum. The species has been tentatively associated with REEVE's *Triton angulatus* as his description and figure appear fairly compatible with the Fiji species.

Morula SCHUMACHER, 1817

Morula SCHUMACHER, 1817, Ess. nouv. syst., pp. 68, 227.

Type species by M *Morula papillosa* SCHUMACHER, 1817 = *Drupa uva* RÖDING, 1798

Discussion: ARAKAWA (1965) established the new genus *Tenguella* with *Purpura granulata* DUCLOS, 1832 as the type species; he erected his new genus on the basis of differences in the number of side-denticles of the rhachidians of the radula in *Morula uva* (RÖDING) and *M. granulata* (DUCLOS). WU (1965a) commented on the variability of the number of side-denticles in the two

species under discussion and doubted the validity of *Tenguella*. The number of side-denticles was found to vary in both species from 1-3 and the length of these denticles also was found to be variable; one can see no merit in retaining this monotypic genus in muricid nomenclature.

The type species of *Morulina* DALL, 1923 is *Ricinuella mutica* LAMARCK, 1822 by original designation, and not *Morulina ceylonica* DALL, 1923 as pointed out by ARAKAWA (1965); the latter species is an immature specimen of *Morula granulata* (DUCLOS, 1832).

The side-cusps of the rhachidians in *Morula* are always simple and not bifid to quadrifid as in *Drupa*.

Morula anaxeres (KIENER, 1835)

(Plate 48, Figures 17, 17a; Text figure 12)

1835. *Purpura cancellata* KIENER, Spec. gén. icon. coq. viv., p. 25; pl. 7, figs. 16, 16a (non QUOY & GAIMARD, 1833)

1835. *Purpura anaxeres* KIENER, Spec. gén. icon. coq. viv., p. 26; pl. 7, figs. 17, 17a

Shell: Variable in colour, dirty grey or brown, nodules occasionally white; interstices sometimes banded with brown. Sculptured with spiral rows of nodules and striae. Labial lip either dark purplish-brown or with occasional white flecks; labial denticles number from 4-5. Columella either fully dark purplish-brown or brown, occasionally streaked with white or light violet, sculptured with 2-4 small and irregular plicae.



Figure 12

Morula anaxeres (KIENER)
Fiji Islands
half row of radular teeth

Radula: Odontophore 3.4 mm long and 0.14 mm wide in an animal with a shell 25.0 mm in length; rows of teeth number 94 (plus 4 nascentes). Rhachidians with a large central cusp, smaller side-cusps, small intermediate denticles and 0-2 side denticles.

L: 10-28 mm; W: 61-79%; HA: 63-70%

Type Locality: L'île Tycopia, des Nouvelles Hébrides.

Habitat: Under basalt rocks, near high tide level, rarely under coral rocks in the intertidal zone. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Morula biconica (BLAINVILLE, 1832)

(Plate 48, Figures 13, 18; Text figures 13, 14)

1832. *Purpura biconica* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 203; pl. 9, fig. 11846. *Riccinula bicatenata* REEVE, Conch. Icon., pl. 6, sp. 481868. *Engina variabilis* PEASE, Amer. Journ. Malac., 3: 275; pl. 23, fig. 9

Shell: Small, whitish to dark grey in colour, pointed at both ends. Sculptured with blackish axial ribs which are generally spinose, and white, prominent and scabrous

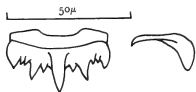


Figure 13

Morula biconica (BLAINVILLE)

Fiji Islands
half row of radular teeth

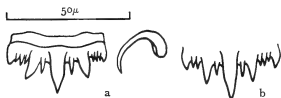


Figure 14

Morula biconica (BLAINVILLE)

Fiji Islands
a. half row of radular teeth
b. part of rhachidian showing variation of cusps

spiral cords. Edge of labial lip white and scabrous, aperture angulate and narrow, violet to dark purple in colour; columella irregularly plicate anteriorly.

Radula: Odontophore 1.16 mm long and 0.06 mm wide in an animal with a shell 11.5 mm in length; rows of teeth number 69 (plus 3 nascentes). Rhachidians have a large central cusp, short or long intermediate denticles, simple side-cusps and 2-3 side denticles; laterals simple and curved.

L: 8-17 mm; **W:** 57-65%; **HA:** 56-63%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Morula granulata (DUCLOS, 1832)

(Plate 49, Figure 19; Text figures 15, 16)

1832. *Purpura granulata* DUCLOS, Ann. Sci. Nat., 26: 9; pl. 2, fig. 91832. *Purpura tuberculata* BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 204; pl. 9, fig. 31835. *Purpura tuberculata cingulifera* KIENER, Spec. gén. icon coq. viv., pl. 5, fig. 10a1908. *Sistrum chrysalis* SOWERBY, Proc. Malac. Soc. London, 8: 17; pl. 1, fig. 51923. *Morulina ceylonica* DALL, Proc. Acad. Nat. Sci. Phila., 75: 305 (specim. juv.)

Shell: Dirty white in colour, ornamented with spiral rows of brown nodules. Sculptured with 5-6 spiral rows of squarish but rounded large brown nodules, earlier whorls with 1-2 rows; interstices finely spirally lirate. Aperture violet, edge of columella and labial lip dark purple-brown; labial lip with 4-5 denticles which are generally bluish-white, columella with 2-4 sinuous plicae. Operculum with a lateral nucleus.



Figure 15

Morula granulata (DUCLOS)

Fiji Islands
half row of radular teeth

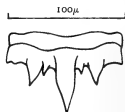


Figure 16

Morula granulata (DUCLOS)

Fiji Islands
Rhachidian of radula

Radula: Odontophore 5.6 mm long and 0.14 mm wide in an animal with a shell 26.0 mm in length; rows of teeth number 203 (plus 12 nascentes). Rhachidians with a

large central cusp, smaller side-cusps and small intermediate denticles; the side denticles number from 1-3, but one specimen examined almost lacked side denticles altogether, apart from a weak hump on one side.

L: 15-30 mm; W: 62-73%; HA: 50-69%

Type Locality: Nouvelle-Hollande.

Habitat: On reefs, under coral rocks, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Morula nodicostata (PEASE, 1868)

(Plate 49, Figure 20; Text figure 17)

1868. *Engina nodicostata* PEASE, Amer. Journ. Conch., 3: 274; pl. 23, fig. 8

1909. *Engina purpureo-cincta* PRESTON, Rec. Ind. Mus., 3: 136

Shell: Small, light violet in colour, nodules white, interstices occasionally dark brown. Sculptured with 3 spiral rows of white round nodules; the nodules nearest the suture are rather large and are bisected by 3-4 spiral cords; earlier whorls with a single row of nodules. Interstices smooth and ornamented with dark brown blotches. Aperture violet in colour, interior of aperture with a broad, white median band; labial lip has 6 small denticles, columella 2-3 short plicae.

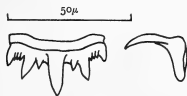


Figure 17

Morula nodicostata (PEASE)

Fiji Islands

half row of radular teeth

Radula: Odontophore 1.28 mm long and 0.06 mm wide in an animal with a shell 9.8 mm in length; rows of teeth number 110 (plus 6 nascentes). Rhachidians have a moderately long central cusp, short intermediate denticles, simple side cusps and 2-3 side denticles; laterals simple and curved.

L: 7-11 mm; W: 61-67%; HA: 60-64%

Type Locality: Paumotu.

Habitat: On reefs, under coral rocks, in shallow water. Uncommon.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: ORR-MAES (1967) figured the radula of *Morula nodicostata* from Cocos-Keeling Islands (Indian

Ocean); the particular specimen examined lacked side-denticles on the rhachidians of the radula. It is obvious that the presence or absence of such side-denticles in the *Morula-Cronia* group of species is a variable feature, and has been observed in other species of *Morula*.

Morula parva (REEVE, 1846)

(Plate 49, Figure 21)

1846. *Ricinuia parva* REEVE, Conch. Icon., pl. 6, sp. 43

1846. *Ricinuia echinata* REEVE, Conch. Icon., pl. 6, sp. 54

1860. *Engina nodulifera* PEASE, Proc. Zool. Soc. London, p. 142

1893. *Sistrum angulatum* SOWERBY, Proc. Malac. Soc. London, 1: 46; pl. 4, fig. 3

Shell: Small, white in colour, ornamented with white and orange nodules and spines. Sculptured with a row of orange nodules at the sutures and prominent white or orange spinose spiral cords; the penultimate whorl has one row of orange nodules at the sutures and 2 spinose spiral cords; interstices finely axially striate. Aperture narrow and elongate, white in colour, interior of aperture with a dark purplish-brown band; labial lip has 4-5 prominent white nodules and the columella 2-3 plicae.

L: 6-10 mm; W: 56-62%; HA: 56-60%

Type Locality: Island of Luzon, Philippines.

Habitat: On reefs, under coral rocks, in shallow water.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Morula spinosa (H. & A. ADAMS, 1853)

(Plate 49, Figures 22, 22a)

1846. *Ricinuia chrysostoma* DESHAYES, REEVE, Conch. Icon., pl. 2, fig. 12b only (non DESHAYES, 1844)

1853. *Pentadactylus (Sistrum) spinosus* H. & A. ADAMS, Gen. rec. Moll., 1: 130 (nom. nov. pro *Ricinuia chrysostoma* REEVE, 1846)

1853. *Murex isotomus* A. ADAMS, Proc. Zool. Soc. London, p. 267

1862. *Ricinuia chrysostoma* DESHAYES, KÜSTER, Conch. Cab., 2nd ed., p. 24; pl. 4, fig. 7 (non DESHAYES, 1844)

1909. *Sistrum andreusii* E. A. SMITH, Proc. Malac. Soc. London, 8: 369; 2 figs.

1923. *Morula ambusta* DALL, Proc. Acad. Nat. Sci. Phila., 75: 304 (nom. nov. pro *Ricinuia chrysostoma* REEVE, 1846)

Shell: Variable in colour, uniformly whitish, yellow or grey, occasionally ornamented with brown spiral cords and spinose nodes. Sculptured with about 9 spinose varices on the body whorl which are arranged in 3-4 spiral rows; penultimate whorl with a single row of spinose nodes. Interstices sculptured with 4-10 brown spiral cords. Aperture elongate and narrow, yellow to orange or

violet in colour, labial lip with about 5 small denticles; columella with 0-5 obsolete short plicae anteriorly.

L: 18-38 mm; W: 63-72%; HA: 57-67%

Type Locality: Islands of Bohol and Ticao, Philippines.

Habitat: On reefs, under coral rocks, in shallow water. Uncommon.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: The holotype of *Murex iostomus* A. ADAMS from the Philippine Islands, ex coll. Cuming, no. 196572 - 23.0×17.8 mm, is in the British Museum (Natural History); it is an immature specimen with dark brown fronds. The types of *Sistrum andrewsi* E. A. SMITH from Christmas Island (Indian Ocean) are in the British Museum collection; the holotype no. 1909.5.8.62 - 25.4 mm in length is a fully mature specimen of the species under discussion.

HABE & KOSUGE (1966, pl. 20, fig. 12) figure this species as *Thaisiella rugosa* (BORN).

Morula uva (RÖDING, 1798)

(Plate 49, Figures 23, 23a; Text figure 18)

1798. *Drupa uva* RÖDING, Mus. Bolten., p. 56, No. 703
 1816. *Ricinula aspera* LAMARCK, Tabl. Encycl. Méth., pl. 395, figs. 4a, 4b
 1816. *Ricinula nodus* LAMARCK, Tabl. Encycl. Méth., p. 2; pl. 395, figs. 6a, 6b
 1817. *Morula papillosa* SCHUMACHER, Ess. nouv. syst., p. 227
 1822. *Ricinula morus* LAMARCK, Anim. s. vert., 7: 232
 1832. *Purpura sphaeridea* DUCLOS, Ann. Sci. Nat., 26: 9; pl. 2, fig. 10
 1852. *Ricinula alba* MÖRCH, Cat. Conch. Yoldi, p. 87
 1868. *Sistrum striatum* PEASE, Amer. Journ. Conch., 3: 276; pl. 23, fig. 12
 1966. *Morula nodulifera* [sic] HABE & KOSUGE, Shells world col., 2: 14; pl. 20, fig. 14 (specim. juv.) (non *Purpura nodulifera* MENKE, 1829)

Shell: White in colour, spiral rows of nodules or short spines blackish-brown. Sculptured with 5 spiral rows of small, blackish-brown nodules, early whorls with 2 such rows; interstices of nodules with 1-4 scabrous spiral cords. In some forms the nodules are spinose, may coalesce and form ill-defined blackish-brown axial folds. Aperture narrow, violet in colour, labial lip with about 4 denticles, basal denticles usually smaller, columella with 2-4 short plicae.

Radula: Odontophore 2.1 mm long and 0.09 mm wide in an animal with a shell 20.6 mm in length; rows of teeth number 162 (plus 8 nascentes). Rhachidian with a large central cusp, smaller side-cusps and small intermediate denticles; side denticles number from 1-3.

L: 13-30 mm; W: 58-70%; HA: 57-63%

Type Locality: None.

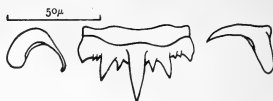


Figure 18

Morula uva (RÖDING)

Fiji Islands

one row of radular teeth - lateral shown in different position

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: *Drupa uva*, *Morula papillosa* and *Ricinula alba* are all based on the same figure from MARTINI (1777, pl. 101, fig. 970). RÖDING (1798) cited an additional reference to LISTER (1685-92, pl. 954, fig. 5), which clearly represents the species *Drupa uva*, and has been erroneously cited by LAMARCK (1822) for his *Murex concatenatus*.

Purpura nodulifera MENKE, 1829, which is the type species of *Oppomorus* IREDALE, 1937, is absolutely unidentifiable. MENKE (1829) described his species as white, conically-ovate, axially nodulose costate, nodes transversely striate; he did not cite a figure and his description is applicable to several species of *Morula*.

The types of *Ricinula aspera* LAMARCK are in the Muséum d'Histoire Naturelle in Geneva. The holotype no. 1107/17/1 - 20.5 mm, is the species *Morula uva*, as is the 15.5 mm paratype. There is a third specimen in the type-collection measuring 21.5×14.3 mm, which is the species *Drupa marginata* (BLAINVILLE). This specimen must have been added after the description, since according to Rosalie de Lamarck's annotation in her father's copy of the "Animaux sans vertèbres," Lamarck possessed only 2 specimens. These two specimens are the form with the spinose nodes. LAMARCK's holotype of *Ricinula nodus* is preserved in the same Museum under no. 1101/18/2 - 24.7×16.4 mm, and also is the species *Morula uva*.

(*Cronia*) H. & A. ADAMS, 1853

Cronia H. & A. ADAMS, 1853, Gen. rec. Moll., 1: 128. Type species is *M. Purpura amygdala* KIENER, 1835

Discussion: In this subgenus are placed species of *Morula* with prominent spiral and sometimes axial sculpture. The

radula of *Cronia* is said to differ from that of *Morula* in the absence of side denticles on the rhachidians of *Cronia*. While this is true as far as the 2 species of *Cronia* from Fiji are concerned, rhachidians devoid of side denticles do occasionally crop up in the *Morula* group (see *M. granulata* DUCLOS and *M. nodicostata* PEASE – *vide* MAES-ORR, 1967).

Morula (Cronia) aurantiaca
(HOMBRON & JAQUINOT, 1853)

(Plate 49, Figure 24)

1853. *Purpura aurantiaca* HOMBRON & JAQUINOT, Voy. Pole. Sud. Ast. & Zélee, pl. 22, figs. 28, 29

1854. *Purpura aurantiaca* HOMBRON & JAQUINOT, Voy. Pole. Sud. Ast. & Zélee, text, p. 91

Shell: Only one juvenile specimen has so far been recorded from the Fiji Islands. The adult shell has strong and broad axial ribs, close-set spiral striae which are occasionally purplish-brown, about 6 labial denticles and a few weak columellar plicae and some denticles.

L: ca. 25 mm

Type Locality: L'île Hogoleu.

Habitat: The single specimen was found under a coral rock near the reef's edge, in 2 feet of water.

Distribution: West Viti Levu. – Pacific.

Discussion: A comparison of specimens of *Morula amygdala* (KIENER) and *M. aurantiaca* (HOMBRON & JAQUINOT) in the United States National Museum would indicate two extremely similar species. *Morula aurantiaca* from Pacific localities seems to be more brightly coloured with a predominance of orange than are specimens of *M. amygdala* from Australian localities.

Morula (Cronia) fuscilla (GMELIN, 1791)

(Plate 49, Figure 25; Text figure 19)

1791. *Murex fuscillum* GMELIN, Syst. Nat., ed. 13, p. 3552, No. 160

1845. *Murex fuscillum* "CHEMNITZ," REEVE, Conch. Icon., pl. 27, fig. 124

1853. *Purpura stellaris* HOMBRON & JAQUINOT, Voy. Pole Sud. Ast. & Zélee, Atlas, pl. 22, figs. 13, 14

1863. *Corallophila confragosa* H. & A. ADAMS, Proc. Zool. Soc. London, p. 432

1868. *Sistrum triangulatum* PEASE, Amer. Journ. Conch., 3: 278; pl. 23, fig. 15

1869. *Murex fuscillum* KÜSTER, Conch. Cab., ed. 2, p. 95; pl. 33, figs. 10, 11

Shell: White or dirty grey, base of depressions in latticed sculpture brown in fresh specimens. Sculptured with 7-8 broad and scabrous axial ribs, which consist of a number

of axially arranged fluted foliations; axial ribs overridden by 3-4 spiral cords, which are either double or triple stranded; towards the base are generally 2 rows of oblique foliated but blunt spines. The axial and spiral sculpture gives rise to recessed "windows" which are brown in colour. Aperture light or dark violet, edge of labial lip slightly fluted and sculptured with 6-7 small regular denticles, columella with 2-4 small denticles anteriorly. Operculum with lateral nucleus.

Young specimens have an angulate labial lip near the juncture of the aperture; the apertural interior is whitish and ornamented with 1-2 broad dark brown bands.

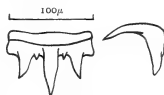


Figure 19

Morula (Cronia) fuscilla (GMELIN)

Fiji Islands
half row of radular teeth

Radula: Odontophore 3.03 mm long and 0.19 mm wide in an animal with a shell 24.5 mm in length; rows of teeth number 129 (plus 7 nascentes). Rhachidians with a long central cusp, small intermediate denticles and simple side cusps; side denticles absent. Central cusp may be shorter in some specimens than in others; intermediate denticles are sometimes close-set to the side cusps. Laterals simple and curved.

L: 18-35 mm; **W:** 63-67%; **HA:** 68-73%

Type Locality: Insulam Pulo Condore, prope Sinam.

Habitat: On reefs, under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. – Indo-Pacific.

Discussion: *Morula fuscilla* (GMELIN) and *M. margaritcola* (BRODERIP, 1832) had a very confused nomenclatural history and both names have been applied to both species interchangeably. GMELIN's (1791) description is equivocal on its own merits, and the interpretation of the species depends on the cited figures from CHEMNITZ (1788, pl. 160, figs. 1524, 1525) and on CHEMNITZ's description. CHEMNITZ (*op. cit.*) clearly described his species as strongly clathrate with deeply recessed "windows" (depressions) which are coloured brown; his description and figure are only applicable to *M. fuscilla* and not to *M. margaritcola*. The species has been correctly figured by REEVE (1845).

Morula (Cronia) margariticola (BRODERIP, 1832)

(Pate 49, Figure 26; Text figure 20)

1832. *Murex margariticola* BRODERIP, Proc. Zool. Soc. London, p. 177
1832. *Purpura fuscilla* LAM., BLAINVILLE, Nouv. Ann. Mus. Hist. Nat., 1: 206; pl. 10, fig. 8 (non *Murex fuscillum* Gmelin, 1791)
1833. *Purpura thiarella* QUOY & GAIMARD, Voy. *Astrolabe*, Zool., 2: 571; pl. 39, figs. 4, 5, 6
1923. *Morula rhyssa* DALL, Proc. Acad. Nat. Sci. Phila., 75: 304 (nom. nov. pro *Ricinula fuscillum* REEVE, 1846)

Shell: Dark brown to almost black in colour, interstices whitish. Sculptured with 9-12 broad axial ribs on the body whorl and 11-14 ribs on the penultimate whorl; axial ribs bisected by scabrous spiral cords which form nodules at the point of intersection. Spiral ridges number from 13-19 on the body whorl and from 5-9 on the penultimate whorl; usually 3-4 ridges are more prominent than the remainder. Aperture light violet or bluish-white, labial lip with 5-6 small denticles, columella with 1-3 elongated denticles anteriorly; parietal wall

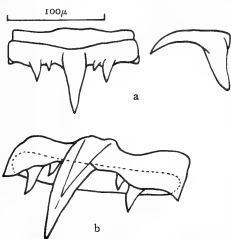


Figure 20

Morula (Cronia) margariticola (BRODERIP)

Fiji Islands

- a. half row of radular teeth
b. ventro-lateral view of rhachidian

occasionally with a brown blotch.

Radula: Odontophore 6.0 mm long and 0.22 mm wide in an animal with a shell 26.0 mm in length; rows of teeth number 161 (plus 6 nascentes). Rhachidians with a long central cusp, small intermediate denticles and simple side cusps; side denticles absent. Laterals simple and curved.

The chitinous teeth are set and hinged onto a darker

coloured base plate (dotted line in Text figure). Early rows of teeth are so worn that only the elongated base-plate remains.

L: 18-37 mm; W: 55-63%; HA: 57-62%

Type Locality: Oceano Pacifico, Lord Hood's Island.

Habitat: Under basalt boulders, near the high tide level and on reefs under coral rocks, in shallow water. Moderately common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific. **Discussion:** There are 3 syntypes of *Murex margariticola* in the British Museum (Natural History) in London. BRODERIP (1832) gave the measurements of the holotype as $1\frac{3}{8} \times \frac{5}{12}$ " (= 34.9 × 16.8 mm), but all 3 syntypes are smaller than the given size. The largest specimen measures 30.0 mm and is a fully mature specimen; this specimen is obviously the holotype. A smaller (25.3 mm) specimen is immature and has an "x" marked inside the aperture.

Maculotriton DALL, 1904

Maculotriton DALL, 1904, Smiths. Misc. Coll., 47: 136. Type species by OD *Triton bracteatus* HINDS, 1844

Discussion: Species of this group are ranellid in appearance and may, or may not, have a varix on some of the whorls. The radula (*cf.* THIELE, 1929) is similar to that of *Cronia* H. & A. ADAMS.

Maculotriton egregius (REEVE, 1844)

(Plate 49, Figure 27)

1844. *Triton egregius* REEVE, Conch. Icon., pl. 18, sp. 78

Shell: White to yellowish in colour, occasionally ornamented with faint brown spots. Sculptured with 2 prominent varices on the body whorl and 3 coarse angulate axial ribs between the varices; penultimate whorl has 8-9 axial ribs and varices become indistinct on earlier whorls. Axial ribs are crossed by spiral cords, some of which are more prominent than others. Aperture creamy-white to light yellow in colour, labial lip with 7-8 elongated denticles, columella either smooth or with 1-2 very small denticles.

L: 20-30 mm; W: 55-60%; HA: 58-62%

Type Locality: Island of Masbate, Philippines.

Habitat: On reefs, under coral rocks, in shallow water. Rare.

Distribution: North Viti Levu. - Philippines.

Discussion The spiral striae are not brown as described by REEVE, and the Fiji species is only tentatively associated with REEVE's *Triton egregius*. *Triton eximius* REEVE,

1844, is another similar species, but the axial ribs are much finer and more numerous.

Vexilla SWAINSON, 1840

Vexilla SWAINSON, 1840, Treat. Malac., pp. 69, 300; fig. 67.

Type species by M *Vexilla picta* SWAINSON, 1840

= *Strombus vexillum* Gmelin, 1791

Discussion: The radula of *Vexilla* (fide COOKE, 1919) is similar to the radula of *Drupella* THIELE, except that the laterals are less broad; it also resembles the radula of *Nassa* RÖDING in some aspects.

Vexilla vexillum (Gmelin, 1791)

(Plate 49, Figure 28)

1791. *Strombus vexillum* Gmelin, Syst. Nat., ed. 13, p. 3520, No. 52

1836. *Purpura taeniata* Powis, Proc. Zool. Soc. London, p. 96

1840. *Vexilla picta* SWAINSON, Treat. Malac., p. 300, fig. 67

Shell: This well-known species hardly requires a detailed description. The shell is dark brown in colour, ornamented with white transverse bands; the aperture is wide, creamy-yellow in colour and the labial lip is denticulate.

L: 15 - 22 mm; W: 54 - 58%; HA: 78 - 84%

Type Locality: Oceano Indico.

Habitat: On reefs, under coral rocks, in shallow water. Uncommon.

Distribution: South Viti Levu. - Indo-Pacific.

Nassa RÖDING, 1798

1789. *Buccinum sertum* BRUGUIÈRE, Encycl. Méth., 1: 262
SD (DALL, 1909) *Nassa picta* RÖDING, 1798 = *Buccinum sertum* BRUGUIÈRE, 1789

Nassa sarta (BRUGUIÈRE, 1789)

(Plate 49, Figure 29; Text figure 21)

1789. *Buccinum sertum* BRUGUIÈRE, Encycl. Méth., 1: 262

1798. *Nassa picta* RÖDING, Mus. Bolten., p. 132, No. 1655

1817. *Stramonita hederacea* SCHUMACHER, Ess. nouv. syst., p. 227

1967. *Nassa sarta* (BRUGUIÈRE), CERNOHORSKY, Mar. shells Pacif., pl. 60, fig. 443 (spawn)

Shell: Reddish-brown in colour, ornamented with broad and irregular white or light yellow zones and bands. Sculptured with from 25 - 35 obsolete axial ribs and 20 - 30 nodulose spiral cords; axial ribs generally more prominent on earlier whorls. Aperture wide, creamy-yellow in colour, edge of labial lip obsoletely denticulate; colu-

mella creamy-white, smooth, apart from an anterior denticle. Operculum dark brown with a lateral nucleus.

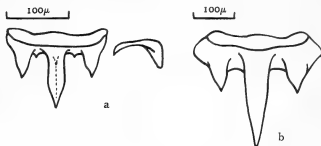


Figure 21

Nassa sarta (BRUGUIÈRE)

Fiji Islands

a. half row of radular teeth

b. rhachidian of radula

Radula: Odontophore is 9.8 mm long and 0.26 mm wide in an animal with a shell 41.0 mm in length; rows of teeth number 151 (plus 10 nascentes). Rhachidian with a long or moderately short central cusp, with or without intermediate denticles and short but massive side cusps; laterals simple and curved.

L: 30 - 60 mm; W: 49 - 56%; HA: 69 - 76%

Type Locality: None.

Habitat: On reefs, under coral rocks, in shallow water. Common.

Distribution: Throughout the Fiji Islands. - Indo-Pacific.

Discussion: The egg capsules of *Nassa sarta* are typically muriciform and rather similar to those of *Chicoreus carneolus* (RÖDING 1798).

SUMMARY

A total of 28 species of Thaidinae have been recorded from the Fiji Islands to date; all the species inhabit the littoral zone. The species recorded from Fiji are distributed over the following genera:

<i>Thais</i>	3
<i>Mancinella</i>	2
<i>Drupa</i>	5
<i>Drupina</i>	1
<i>Drupella</i>	4
<i>Morula</i>	7
(<i>Cronia</i>)	3
<i>Maculotriton</i>	1
<i>Vexilla</i>	1
<i>Nassa</i>	1
Total	28 species

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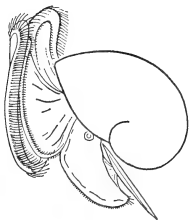
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Effects of Turbidity-Producing Substances in Sea Water on Eggs and Larvae of Three Genera of Bivalve Mollusks

BY

HARRY C. DAVIS

AND

HERBERT HIDU¹

Bureau of Commercial Fisheries, Biological Laboratory, Milford, Connecticut 06460

(7 Text figures)

INTRODUCTION

THE EFFECT OF SILT or other turbidity-producing substances on shellfish generally, and particularly on oysters and their larvae, has long been of interest to biologists and to shellfish producers. In addition to the obvious damage to oyster beds silted over in harbor dredging and in building bridges and roads in estuarine areas, it has been suspected that turbidity from these sources affected larval development and setting of oysters. LUNZ (1938), however, found no harmful effects from high turbidities on adult oysters or on spawning and setting, in his field study during the dredging of the Intra-Coastal Waterway of South Carolina, except where the oysters were actually buried by the spoil.

Only a few studies of the effects of turbidity have been made under controlled conditions. LOOSANOFF & TOMMERS (1948) who, in laboratory experiments, studied the effects of a series of concentrations of turbidity-producing materials on adult oysters found that 0.1 gm of silt per liter of sea water reduced the pumping rate of adult oysters by 57% and that concentrations of 3 and 4 gms per liter reduced pumping by 94%. They reported generally similar results with kaolin and chalk, and that 0.5 gm of Fuller's earth per liter reduced pumping by 60%.

More recently, DAVIS (1960) determined quantitatively the effects of a series of concentrations of several turbidity-producing substances on the percentage of eggs of the hard clam (*Mercenaria* (= *Venus*) *mercenaria*) that developed into normal straight-hinge larvae and on

the survival and growth of the larvae. In the work reported here the same techniques were used to determine the effects of several concentrations of silt, clay, and Fuller's earth on embryonic development of the American oyster (*Crassostrea virginica*) and on survival and growth of larvae of the American oyster and the European oyster (*Ostrea edulis*).

In addition, a series of experiments was run to compare the effects of different-sized particles of pure silicon dioxide on embryos and larvae of hard clams and American oysters, in an attempt to determine the effect of particle size of a suspended material, as opposed to possible effects of its chemical composition.

MATERIALS AND METHODS

The turbidity-producing materials used — silt, clay (kaolin N. F. VII Mallinckrodt), and Fuller's earth (dusting powder, McKesson), — were the same as those used in the experiments on clam larvae (DAVIS, 1960). The silt was collected from the bed of Milford Harbor just upstream from the laboratory. It was washed through a 325-mesh screen to remove larger particles and debris, after which it was collected in a Buchner funnel and washed with distilled water to remove the salts. It was then dried at 200° C and the dried cake was ground in an all-ceramic jar mill. The Fuller's earth was similarly ground.

Fisher's floated silica powder (about 240 mesh) was used for the experiments to determine the effect of particle

¹ Present address: University of Maryland, Natural Resources Institute, Box 38, Solomons, Maryland 20688

* Mention of trade names does not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

size. It was suspended in distilled water and allowed to settle in a tall column. The settled plug was pushed out and cut into sections. The sections used were chosen to give particle sizes within the ranges: $< 5\mu$, $5 - 25\mu$, and $25 - 50\mu$. Particle-size determinations, made by Dr. Keith E. Chave, Director, Marine Science Center, Lehigh University, are given in Table 1.

Table 1

Percentages by weight of particles of different sizes composing the materials tested ³

Particle Sizes	Silt	Kaolin	Fuller's Earth
$> 62.5\mu$	8.24	12.06	8.87
$62.5 - 15.6\mu$	28.36	6.03	18.16
$15.6 - 3.9\mu$	39.10	10.72	26.10
$3.9 - 0.98\mu$	9.85	44.87	21.27
$< 0.98\mu$	14.54	26.32	25.60
Silicon Dioxide			
	$< 5\mu$	$5 - 25\mu$	$25 - 50\mu$
$125 - 64\mu$	—	trace	1.8
$62.4 - 31.2\mu$	—	1.3	17.3
$31.2 - 15.6\mu$	—	9.3	64.9
$15.6 - 7.8\mu$	trace	84.8	16.0
$7.8 - 3.9\mu$	4.1	2.4	trace
$3.9 - 1.95\mu$	56.9	2.3	—
$1.95 - 0.98\mu$	18.3	trace	—
$0.98 - 0.49\mu$	17.2	—	—
$< 0.49\mu$	3.5	—	—

³ Particle size determinations made by Dr. Keith E. Chave, Director, Marine Science Center, Lehigh University, Bethlehem, Pennsylvania

In our larval cultures appreciable quantities of kaolin and Fuller's earth, particularly at low concentrations, flocculated as particles 100μ or more in size. Dr. Chave reported similar flocculations in his particle size determinations and believed, "the significant percentages of material greater than 62.5μ probably represent flocculation of particles in the water" (personal communication).

Concentrations of all materials are expressed as grams of dry powder per liter. In making up a suspension, a weighed quantity of the powdered material was thoroughly mixed with sea water and the various experimental concentrations were prepared by serial dilution.

The methods for obtaining fertilized oyster eggs out of season have been described, as have methods for determining the percentage of eggs developing to the straight-hinge larval stage, and for determining the survival and rate of growth of larvae (LOOSANOFF & DAVIS, 1963).

In all experiments the sea water in the larval cultures was changed every second day and larvae in all cultures were fed a mixture of *Isochrysis galbana* and *Monochrysis lutheri* daily. The quantity and quality of food were the same for all cultures within an experiment since each culture received an equal volume of algal food. The quantity and quality of food in successive experiments, however, were not necessarily equal, due to changes in the algal cultures and sea water. Duplicate cultures were used in each experiment at each concentration of suspended material. Temperatures of all cultures were maintained between 23°C and 25°C and salinity between 26 and 27.5‰ .

European oyster larvae may start setting 8 days after release under optimum conditions and are, thereafter, not available for quantitative sampling. Consequently, samples for determining percentage survival and rate of growth of these larvae were taken on the 7th day after the larvae were released, i.e., after 7 days at experimental conditions. Few American oyster larvae set before the 14th day even under near-optimum conditions. Samples of American oyster larvae, therefore, were taken on the 14th day after fertilization or after 12 days at the experimental conditions. Some clam larvae may reach setting size and undergo metamorphosis as early as the 8th day, but even these early post-setting stages can be suspended and accurate quantitative samples can be taken as late as the 12th day after fertilization, i.e., after 10 days at the experimental conditions.

EFFECTS ON EMBRYONIC DEVELOPMENT

Silt was more harmful to American oyster embryos than either clay (kaolin) or Fuller's earth. As little as 0.188g/l of silt had a significant effect on the percentage of oyster eggs developing to the straight-hinge larval stage, whereas Fuller's earth had no significant effect until concentrations exceeded 1g/l and kaolin had no significant effect until concentrations exceeded 2g/l (Table 2). Moreover, in only one experiment did any (3%) of the oyster eggs develop normally in 1g/l of silt, whereas the average number developing normally, for all experiments in 4g/l was 26% for Fuller's earth and 76% in kaolin.

DAVIS (1960) found that a normal number of clam eggs developed in silt concentrations as high as 0.75g/l , but it required only 0.125g/l of Fuller's earth or 0.5g/l of kaolin to cause a significant reduction in the number of clam eggs developing normally. The experiments reported here show that oyster embryos are less tolerant of silt than are clam embryos, but oyster embryos are considerably more tolerant of kaolin and Fuller's earth

than are clam embryos. Results with clam eggs and with oyster eggs were similar, however, in that no embryos of either species developed normally at the higher concentrations of silt, whereas a significant number of embryos of both species did develop normally in even the highest concentrations (4g/l) of kaolin and Fuller's earth.

Table 2

Percentage of clam and American oyster eggs developing to the straight-hinge larval stage in different concentrations of suspended materials. The number of eggs developing to the straight-hinge stage in control cultures was considered 100%

Concentration grams/liter	Silt		Kaolin		Fuller's Earth	
	Clam*	Oyster	Clam*	Oyster	Clam*	Oyster
0.0 (controls)	100	100	100	100	100	100
0.125	95	95	82	100	75	104
0.188	90	78	—	—	—	—
0.250	96	73	82	100	61	103
0.375	93	66	—	—	—	—
0.500	99	31	52	104	41	102
0.750	92	9	—	—	—	—
1.000	79	3	37	108	57	98
1.500	65	0	—	—	—	—
2.000	39	0	49	94	50	79
3.000	0	0	—	—	—	—
4.000	0	0	42	76	45	26

	Silicon Dioxide Particles					
	< 5 μ		5 - 25 μ		25 - 50 μ	
	Clam	Oyster	Clam	Oyster	Clam	Oyster
0.0 (controls)	100	100	100	100	100	100
0.125	106	94	106	105	114	112
0.250	105	109	96	104	98	94
0.500	105	93	98	106	102	100
1.000	99	107	94	103	98	111
2.000	85	114	92	109	96	109
4.000	69	123	103	96	92	117

* from DAVIS, 1960

The experiments with silt, kaolin, and Fuller's earth led us to conclude, tentatively, that the larger particles present in silt and, to a lesser extent, in kaolin and Fuller's earth were primarily responsible for the deleterious effects on oyster eggs, whereas the smaller particles, most numerous in kaolin, were probably responsible for the effect on clam eggs.

The percentage of oyster eggs developing normally did not decrease significantly, however, in any of the various concentrations of silicon dioxide tested, regardless of particle size. Moreover, only at the highest concentrations

of the smallest particles of silicon dioxide did the percentage of clam eggs developing normally decrease significantly. Obviously, then, the decreases in the percentage of clam and oyster eggs developing in the higher concentrations of silt, kaolin, and Fuller's earth, and the differences between their effects are not wholly the result of differences in particle size. Although silicon dioxide has a higher density than the other substances tested and fewer particles of any given size per unit of weight, it seems unlikely that this difference alone can account for the difference in results. Although 4g/l of silicon dioxide gave no reduction in the percentage of oyster eggs developing normally, only 1g/l of silt reduced the number by 97%. Even if the silicon dioxide were 4 times as dense as the silt, there should be at least as many particles in 4g of silicon dioxide as in 1g of silt.

EFFECTS ON SURVIVAL OF LARVAE

European oyster larvae were the most hardy of the 3 species tested in that survival did not decrease significantly in concentrations up to 4g/l of any of the suspended material used, except kaolin (Figures 1a, 2a, 3a). This result is in striking contrast to that with clam larvae, which showed a fair survival in 4g/l of silt but no survival in 1g/l of either kaolin or Fuller's earth (DAVIS, 1960). American oyster larvae were less tolerant of silt than either European oyster larvae or clam larvae, for as little as 0.75g/l of silt caused a significant decrease in the percentage of American oyster larvae surviving. American oyster larvae, nevertheless, were more tolerant of kaolin and Fuller's earth than were clam larvae. Approximately 27 to 34% survived in 4g/l of either kaolin or Fuller's earth.

We noted that many clam larvae, in the presence of the smaller particles of kaolin and Fuller's earth, eventually lost their ability to reject these particles. The larvae then ingested the particles, the stomach became packed, and the larvae died. We postulated that both species of oyster larvae were better able to reject these small particles and, hence, showed a lower mortality than clam larvae in kaolin and Fuller's earth.

The experiments with silicon dioxide indicated that it is primarily the smaller particles that affect survival. Both hard clam (Figure 4a) and American oyster (Figure 5a) larvae suffered severe mortality at comparatively low (0.5g/l) concentrations of the smallest (up to 5 μ) particles, whereas neither species suffered significant mortality at values as great as 4g/l of the larger particles; even at 4g/l of the smallest particles of silicon dioxide, however, mortality was not as great as with lesser concentrations of some of the other materials.

The effects of kaolin and Fuller's earth, for example, particularly at higher concentrations, on survival and growth of clam larvae were more drastic than would be expected from the effect of silicon particles of similar size. Nevertheless, the much greater mortality of clam and oyster larvae in the presence of the smallest particles of silicon dioxide, as compared to mortality in the presence of larger particles, did follow the same trend as with kaolin and Fuller's earth. The observation of numerous oyster larvae with their guts packed with silicon particles demonstrated that the American oyster larvae could not reject these small silicon dioxide particles as successfully as they did the particles of kaolin or Fuller's earth. European oyster larvae, however, were apparently capable of rejecting all suspended particles and, hence, suffered little mortality.

EFFECTS ON GROWTH OF LARVAE

The effects of suspended material on growth of both species of oyster larvae were somewhat different from their effects on clam larvae. For example, silt had no deleterious effect on growth of clam larvae until concentrations reached 1g/l, and growth was not reduced drastically until silt concentrations were in excess of 2g/l. Moreover, clam larvae showed evidence of feeding even in 4g/l of silt although growth was negligible (DAVIS, 1960). Larvae of American and European oysters reared in 0.75g/l of silt, however, suffered a significant reduction in growth and those in 2g/l and over did not grow at all (Figure 1b). At 3g/l and 4g/l of silt all American oyster larvae eventually died. Even though most European oyster larvae survived at all silt concentrations, reduction in growth of these larvae at concentrations of 1g/l and less was more drastic than for clam or American oyster larvae.

Conversely, both species of oyster larvae tolerated kaolin (Figure 2b) and Fuller's earth (Figure 3b) better than clam larvae did. Growth of clam larvae was drastically reduced by 0.5g/l of either kaolin or Fuller's earth and all clam larvae were killed by 1g/l of either material (DAVIS, 1960). Growth of American oyster larvae, on the other hand, was not significantly reduced by 1g/l of kaolin. Moreover, in at least 3 of the 4 experiments these oyster larvae showed appreciable growth in 2g/l of kaolin and growth of European oyster larvae was significantly affected only in concentrations of 4g/l of kaolin (Figure 2b).

Fuller's earth had a more deleterious effect than kaolin on growth of both species of oyster larvae. Nevertheless, both species showed significant growth and good survival at 1g/l of Fuller's earth, but American oyster larvae showed only fair survival and no appreciable growth at

2g/l. European oyster larvae still showed good survival and fair growth even at 2g/l of Fuller's earth (Figure 3b).

Growth of clam larvae was not seriously affected by concentrations up to 2g/l of either the 25-50 μ or the 5-25 μ particles of silicon dioxide (Figure 4b). Even in the presence of the smallest particles (<5 μ) growth of the clam larvae that survived was fairly good. Results with American oyster larvae (Figure 5b) were similar. The rate of growth decreased at almost all concentrations of all particle sizes of silicon dioxide, but the largest particles interfered least with growth of these larvae. Even in the presence of the smallest particles that interfered most, with oyster larvae, as with clam larvae, those that survived showed appreciable growth.

VARIATIONS AMONG SUCCESSIVE EXPERIMENTS AND POSSIBLE CAUSES

DAVIS & CHANLEY (1956) pointed out that the first evidence of toxicity to larvae, either of toxins produced by living microorganisms or of synthetic chemical toxins, was a reduction in the growth rate of larvae. It was suggested by DAVIS (1960) that the more rapid growth of clam larvae in the lower concentrations of silt, kaolin, and Fuller's earth was due, in part, to chelation or adsorption of toxic substances present in the sea water or produced by the algae and bacterial contaminants added as foods.

In the 3 experiments with silt, the effect of silt in concentrations of 0.5g/l and lower was to increase the rate of growth of the oyster larvae. The rate of growth of the larvae differed somewhat in the 3 consecutive experiments, but the increases in length, when converted to percentages of the length increase in control cultures, were in general agreement and results of the 3 experiments were averaged to give the curve plotted in Figure 1b.

Four experiments were run with kaolin and Fuller's earth concurrently but subsequent to the experiments with silt and, consequently, the food cultures and sea water were different. Growth of larvae in the control cultures was poor in Experiments 2 and 3, of the 4 consecutive experiments, and the shapes of the curves are different from those of Experiments 1 and 4 in which growth of larvae in control cultures was normal (Figures 6, 7). We believe the poor growth of larvae in the control cultures was due to an excessive amount of toxins produced by microorganisms present in the sea water or, possibly, by toxin-producing bacteria contaminating our algal food cultures.

When the quantity of toxins appeared to be low (Experiments 1, 4) ("normal" for our laboratory cultures)

growth was optimum in about 0.5g/l of kaolin, i. e., 0.5g/l was sufficient to adsorb the toxins (Figure 6). When the quantity of toxins appeared to be greater (Experiments 2, 3), about 1g/l of kaolin was required to adsorb the toxins and give optimum growth, whereas at the lower concentrations the harmful effects of suspended materials and toxins almost appeared to be additive (Figure 6).

The data from the experiments with Fuller's earth gave less clear-cut but similar results. When the concentration of toxins was low (Experiments 1, 4) 0.25g to 0.5g/l was sufficient to adsorb the toxins, whereas 0.5g/l or, perhaps, slightly more was required when the concentration of toxins was high (Experiments 2, 3, and Figure 7).

Of the materials used, only silt caused any appreciable change in the pH of our sea water. Even with silt the maximum change in pH was from 7.5 (normal for our laboratory sea water) to 6.40. Other experiments have shown that at pH 6.40 the decrease in the proportion of clam or oyster eggs developing into normal larvae and in the survival and growth of larvae of these two genera of bivalves is less drastic than is caused by silt alone (CALABRESE & DAVIS, 1966). A portion of the effect of silt may be attributable, nevertheless, to its effect on the pH of sea water.

Other possible causes for the difference in effects of silt, kaolin, Fuller's earth, and silicon dioxide include possible soluble toxic components or, more probably, differences in their adsorptive and chelating characteristics. Silt, a mixture of organic and inorganic materials, would seem most likely to contain toxic components and highly effective chelators capable of causing mortality of embryos or larvae by over-chelation.

Our experiments indicate that bivalve larvae can tolerate turbidities higher than those normally encountered in natural waters, and that under certain circumstances low concentrations of turbidity-producing materials may be beneficial. Nevertheless, higher silt concentrations, such as those produced by dredging or filling operations, could be detrimental to bivalve larvae, both as a direct effect of the particulate matter and, indirectly, as a result of lowered pH. We also suspect that, in natural waters, disturbing the bottom may release numerous bacteria, some of which may be toxic, and organic enrichment sufficient to enable these bacteria to reproduce rapidly. The effect of dredging, therefore, may be more deleterious to bivalve larvae than would be indicated by their tolerance to turbidity-producing materials alone.

SUMMARY

1. As little as 0.188g/l of silt caused a significant decrease in the percentage of oyster eggs developing nor-

mally, as did 3g/l of kaolin or 4g/l of Fuller's earth.

2. The percentage of American oyster eggs developing normally was not affected by concentrations of silicon dioxide of 4g/l, regardless of particle size. Clam eggs were affected only at 4g/l of the smallest particles ($< 5\mu$).

3. Survival of European oyster larvae was less affected by silt, kaolin, and Fuller's earth than was survival of larvae of either American oysters or hard clams.

4. The smallest particles ($< 5\mu$) of silicon dioxide had the greatest effect on survival and growth of clam and oyster larvae. Larger particles (5 - 25 μ and 25 - 50 μ) had little effect on survival of either species or on growth of clam larvae. Growth of American oyster larvae decreased progressively as the size of silicon dioxide particles was decreased.

5. Growth of European oyster larvae was less affected by kaolin and Fuller's earth than was growth of larvae of the American oyster or hard clam, but was more strongly affected by silt than was growth of larvae of either of the other two species.

6. Bivalve larvae grew faster in low concentrations of turbidity-producing substances than in clear sea water, possibly because the suspended particles chelate or adsorb toxins present in larval cultures. The "optimum" concentration of suspended material probably depends upon the amount of toxin to be chelated or adsorbed.

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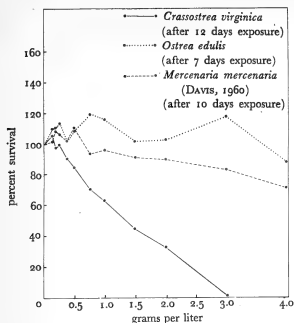


Figure 1a

Percentage survival of three genera of bivalve larvae reared in sea water suspensions containing different concentrations of silt. The number of larvae surviving in control cultures was considered 100%.

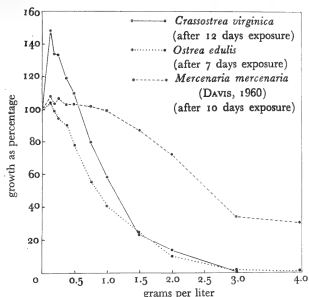


Figure 1b

Increase in mean length of three genera of bivalve larvae, grown in different concentrations of suspended silt, plotted as percentages of the increase in mean length of larvae in control cultures.

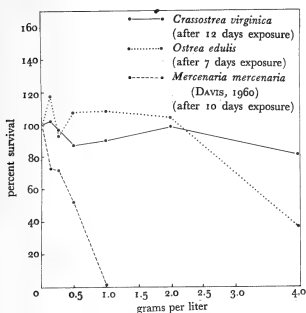


Figure 2a

Percentage survival of three genera of bivalve larvae reared in different concentrations of suspended kaolin. The number of larvae surviving in control cultures was considered 100%.

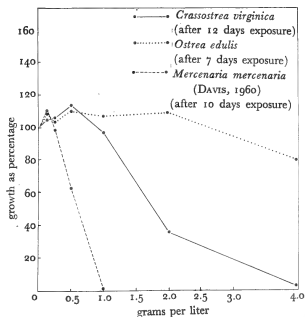


Figure 2b

Increase in mean length of three genera of bivalve larvae, grown in different concentrations of suspended kaolin, plotted as percentages of the increase in mean length of larvae in control cultures.

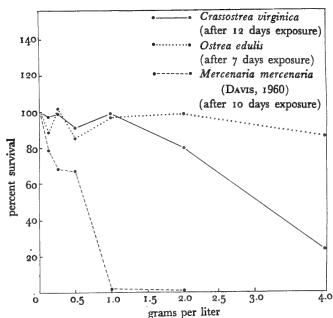


Figure 3a

Percentage survival of three genera of bivalve larvae reared in different concentrations of suspended Fuller's earth. The number of larvae surviving in control cultures was considered 100%.

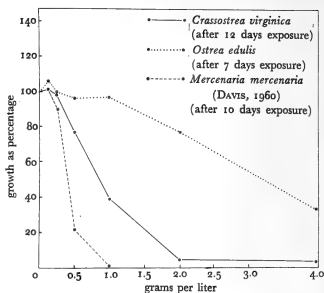


Figure 3b

Increase in mean length of three genera of bivalve larvae, grown in different concentrations of suspended Fuller's earth, plotted as percentages of the increase in mean length of larvae in control cultures.

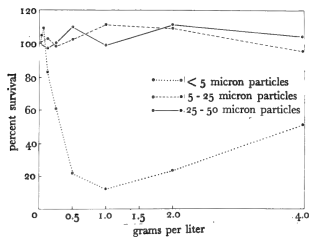


Figure 4a

Percentage survival of clam larvae reared in different concentrations of suspended silicon dioxide particles of three different particle sizes.

The number of larvae surviving in control cultures was considered 100%.

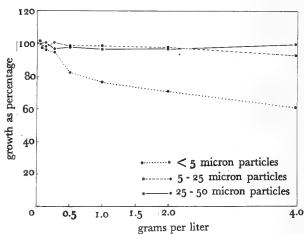


Figure 4b

Increase in mean length of clam larvae grown in different concentrations of suspended silicon dioxide of three different particle sizes. The increase in mean length is plotted as a percentage of the increase in mean length of larvae in control cultures.

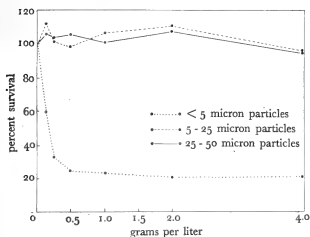


Figure 5 a

Percentage survival of American oyster larvae reared in different concentrations of suspended silicon dioxide particles of three different sizes. The number of larvae surviving in control cultures was considered 100%.

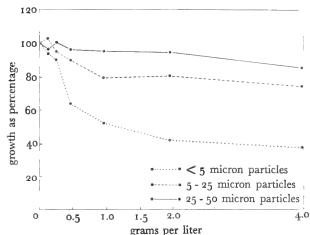


Figure 5 b

Increase in mean length of American oyster larvae grown in different concentrations of suspended silicon dioxide of three different particle sizes. The increase in mean length is plotted as a percentage of the increase in mean length of larvae in control cultures.

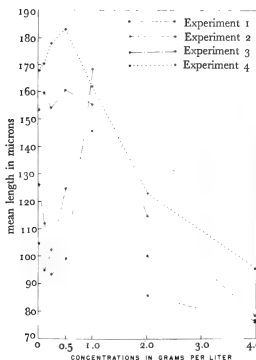


Figure 6

Effect of different concentrations of kaolin on mean length of American oyster larvae at 14 days in four separate experiments.

Points plotted are averages for duplicate cultures at each concentration in each experiment.

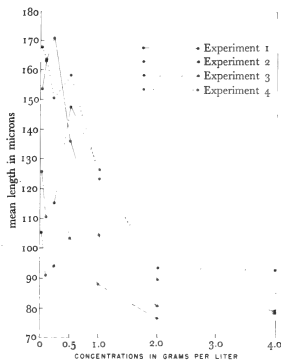


Figure 7

Effect of different concentrations of suspended Fuller's earth on mean length of American oyster larvae at 14 days in four separate experiments. Points plotted are averages for duplicate cultures at each concentration in each experiment.

A New Species of *Murexsul* from the Galápagos Islands

BY

WILLIAM K. EMERSON

AND

ANTHONY D'ATTILIO

Department of Living Invertebrates,
American Museum of Natural History

Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 50; 1 Text figure)

THROUGH THE KINDNESS of Mrs. Jacqueline DeRoy and Mrs. Carmen Angermeyer of Academy Bay, Santa Cruz Island, Galápagos Islands, we are privileged to describe a new muricid species which we have placed in the genus *Murexsul* on the basis of shell morphology and radular-opercular characters.

Murexsul jacuelinae EMERSON & D'ATTILIO, spec. nov.

Plate 50; Text figure 1

The shell is small, pink, flesh-colored, with numerous, fine, deeply cut, scabrous, spiral ridges; there are 5 post-nuclear whorls preserved, the nepionic whorls being eroded. The fusiform shell has a centrally located, medium sized aperture; the whorls are angled, with an impressed suture, and there are, on the penultimate whorl of the spire, 8 spiral ridges that are of equal size with the interspaces; these are crossed axially by 8 varices, at the most elevated point of which the spiral ridges develop into upturned open spines; both spiral and axial sculpturing gradually increase in number on each succeeding whorl. The body whorl has 6 varices crossed by 5 spiral ridges, which are similar in character to those of the spire, above the shoulder angle; these are followed by 6 ridges

below the shoulder; the canal has 4 additional ridges, with some of intermediate and minor development. The varices, on the elevated portion of the body whorl, have spiral ridges that form more prominent spines than those developed on the spire.

The aperture is ovate, vividly colored a rosy-violet; the inner lip is elevated mostly posteriorly; the crenulated labrum is sculptured within, reflecting the exterior ridges. The siphonal canal is long, narrowly opened, and slightly recurved; it is broad above where it possesses only growth striae on its flattened surface; below it is narrowly tube-like; on the left the canal bears the distal portion of previous canals which are the projecting ends of the varices of the body whorl.

The operculum is muricid, with a basal nucleus. The radular characters (Text figure 1) suggest placement of the new species in the genus *Murexsul* IREDALE, 1915. Drawings of the radula of *Murex octogonus* QUOY & GAIMARD, 1833, the type species of *Murexsul*, were previously published by HUTTON, (1883; pl. 13, fig. C) and by PONDER (1968, pl. 1, fig. 1).

Measurements: Holotype, 20.4 mm in length, 11.1 mm in width; largest paratype, 26.3 mm in length, 15.6 mm in width.

Explanation of Plate 50

Murexsul jacuelinae EMERSON & D'ATTILIO, spec. nov.

Figures 1, 2: Holotype (A. M. N. H. No. 147968), 100 m off Tagus Cove, Isabella Island, Galápagos Islands; $\times 3$. Operculum in aperture.

Figures 3, 4: Paratype (A. M. N. H. No. 147969), 50 m off Barrington Island, Galápagos Islands; $\times 3$. Note foreign growths and drill hole.

Figures 5, 6: Paratype (coll. D'Attilio) 30 m off Jervis Island, Galápagos Islands; $\times 3$. Labrum broken.



Figure 1



Figure 2



Figure 3



Figure 4

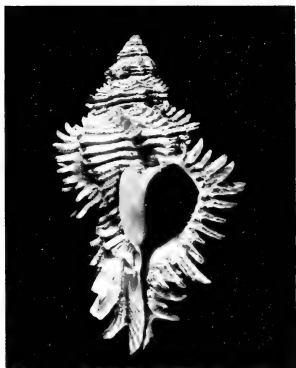
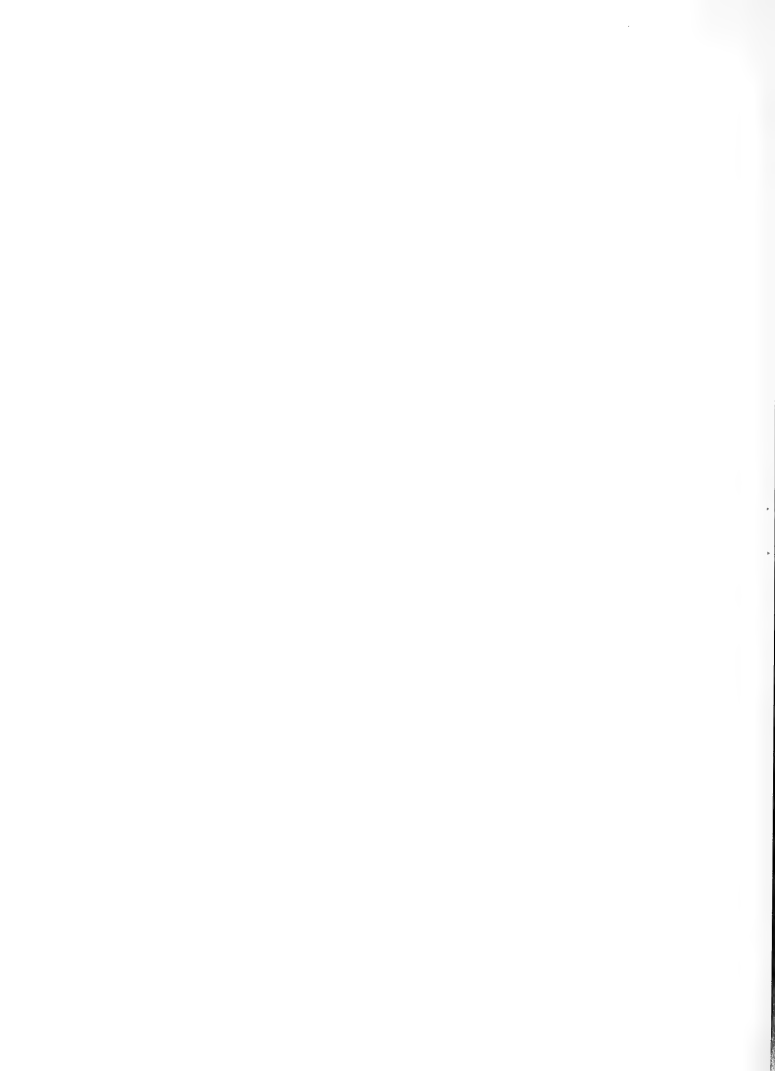


Figure 5



Figure 6



Type Locality: Off Tagus Cove, Isabella Island, Galápagos Islands in 100 m, January 30, 1968, by the DeRoys, holotype (Plate 50, Figures 1, 2) and 2 paratypes.



Figure 1

Murexsul jacquelinae EMERSON & D'ATTILIO, spec. nov.

Two lateral teeth and a central tooth from the radula of the holotype; $\times 300$

Remarks: The new Galapagan species may be distinguished from its apparent congeners in the eastern Pacific, *Murexsul vittatus* (BRODERIP, 1833) and *Murexsul lappa* (BRODERIP, 1833), by their possession of heavier and coarser sculptured shells that have fewer spiral ridges. Additionally, the shells of *M. vittatus* may be essentially white or may be colored with brown or blackish bands, and the shells of *M. lappa* are commonly white with 2 broad, ochre-colored bands. The aperture of the new Galapagan species is distinctively colored a rosy-violet.

Type Repositories: Holotype. A. M. N. H. No. 147968 and 2 paratypes from the type locality (DeRoy Collection); 3 paratypes from off Barrington Island, Galápagos Islands in 50 m, by the DeRoys, December 29, 1967 (1 - A. M. N. H. No. 147969; 2 - D'Attilio Collection); 1 paratype from off North Barrington Island, Galápagos Islands, in 55 - 64 m, by the Angermeyers, 1967 (ex Angermeyer Collection); 1 paratype from off Jervis Island, Galápagos

Islands, in 30 m, by the DeRoys, March 22, 1967 (DeRoy Collection).

The largest paratype specimen represents a more mature growth stage than that of the holotype (Plate 50, Figures 1, 2) and a figured paratype (Plate 50, Figures 3, 4). This specimen, here illustrated, Plate 50, Figures 5, 6, which was collected dead, is bleached white, with the labrum badly broken. It shows the mature character of the elevated ridges with the long, spiny processes on the varices.

ACKNOWLEDGMENTS

In addition to the Angermeyers and the DeRoys, we are indebted to Professor Masao Azuma of Nishinomiya, Japan, who kindly provided us with the original radular drawing from which we have drafted the present drawing. Our colleague, William E. Old, Jr., assisted us in various ways.

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Predators on *Olivella biplicata*, Including a Species-Specific Predator Avoidance Response

BY

D. CRAIG EDWARDS¹

Department of Zoology, University of Chicago,
and Department of Oceanography, Scripps Institution of Oceanography, La Jolla, California

(Plate 51; 1 Text figure)

IN THE COURSE OF MORE GENERAL STUDIES OF *Olivella biplicata* (SOWERBY, 1825) (EDWARDS, 1965, 1968) it has been possible to assemble for the first time a list of its predators with some observations on their feeding. The predators include *Octopus* sp., *Conus californicus* HINDS, 1844, *Polinices reclusianus* (DESHAYES, 1839), *Pisaster brevispinus* (STIMPSON, 1857), *Astropecten armatus* GRAY, 1840, one or more species of crabs, shore birds, and man. *Olivella* was also found to exhibit a specific, vigorous escape response to *Pisaster brevispinus*, but not to *P. ochraceus* (BRANDT, 1835) or *Astropecten armatus*. The new information on predators extends food lists and will aid community energetics studies; it should also facilitate further studies of the ecology of *O. biplicata* and could form the basis of a thorough investigation of the effect of predation on this long-lived (see below), abundant, intertidal gastropod. The demonstration of a species-specific avoidance response to a predator adds to the growing literature on this ecologically important form of chemical communication.

Field work was done from Newport, Oregon, to Ensenada, Baja California. Most observations were made at low tide when the animals were exposed or shallowly immersed; snorkeling was also used at most sites. Laboratory studies were done at the Oregon Institute of Marine Biology, Charleston, Oregon, and at Scripps Institution of Oceanography, La Jolla, California.

PREDATORS

The most diverse and possibly the chief predators on adult *Olivella biplicata* are other mollusks. Numerous laboratory and field observations by R. T. Paine (personal communication), N. Fotheringham (personal communication), and myself show *O. biplicata* of all sizes (8.5 to 26.1 mm)

are eaten by small *Octopus bimaculoides* PICKFORD & MCCONNAUGHEY, 1949, or *O. bimaculatus* VERRILL, 1883, or both, in southern California. (*Olivella* size data herein-after are shell lengths from siphonal canal to apex.) The octopuses emerge from beneath rocks on sand flats, seize *Olivella*, drill a very small hole (ca. 0.5 mm maximum external diameter) near the shell apex (edge of body whorl or on whorl above; Plate 51, Figure 1), and apparently inject a paralyzing venom (see PILSON & TAYLOR, 1961). The effect of *Octopus* predation on natural *Olivella* populations, however, appears small: very few empty *Olivella* shells bear *Octopus* bore holes (see below), and the proportion remains small even when shells are collected near a regularly occupied *Octopus* burrow.

Several gastropods eat *Olivella*. In the San Diego, California, area *Conus californicus* eats *O. biplicata* both in aquaria and in the field (SAUNDERS & WOLFSON, 1961); and, of 56 known observations of prey taken by this predator in nature, more (10) were of *O. biplicata* than any other species (KOHN, 1966). *Conus* swallows its prey whole and may prefer small *Olivella*: two large *C. californicus* (> 25 mm) kept in an aquarium provided with running sea water, a sand substrate, and 20 medium to large *O. biplicata* (20–28 mm) for three weeks ate no *Olivella*.

Another carnivorous prosobranch, *Polinices reclusianus*, widely co-occurs with *Olivella biplicata* in California and Baja California, and a small percentage of empty *O. biplicata* shells from the field regularly bears the characteristic countersunk bore hole of this predator (Plate 51, Figure 2). *Polinices*, which is rarely abundant, feeds primarily on bivalves; it also accepts gastropods as alternative food, but probably takes few olives in nature (see below). The maximum rate of predation on *O. biplicata*, were no other prey available, was determined, using three *Polinices* of similar size (means and standard errors: 33.43 ± 1.05 mm shell height $\times 29.50 \pm 1.15$ mm shell width; 1531 ± 234 mgm shell-free dry weight). The predators were first acclimated to eating *Olivella* in cap-

¹ Present address: Department of Zoology, University of Massachusetts, Amherst, Massachusetts 01002

tivity and then placed in an aquarium provided with running sea water, a sand substrate, and ca. 20 prey ranging in size from 18.3 to 28.4 mm. The three *Polinices* (4593 mgm total shell-free dry weight) ate 13 *O. biplicata* (4198 mgm total shell-free dry weight) in 15 days (3-18 November 1965); thus, the *Polinices* consumed 6% of their own dry weight per day. This feeding rate, while exceeding the 1.2 to 4.6% rate of some species of *Conus* in the tropics (Kohn, 1959, and in press), falls far short of the 15-25% of body weight per day rates given for other predatory gastropods, including *Polinices duplicatus* (SAV, 1822) and other *Conus* (THORSON, 1958; KOHN, in press). Possibly the non-preferred prey status of *Olivella* and the season of observations - many predaceous gastropods feed little, if at all, in winter - or both affected the feeding rate of *P. reclusianus*.

The feeding behavior of *Polinices reclusianus* is like that described for other naticids (GONOR, 1965; FRETTER & GRAHAM, 1962). Prey are seized with the propodium, drawn under the predator, and wrapped up in the concave ventral surface of the mesopodium. Under attack, *Olivella* moves with strong forward lurches and often forces its way under or around the enclosing mesopodium; escapes then continue their lurching progression for 8-10 cm. *Polinices reclusianus* may carry captured prey around in the mesopodium before burrowing into the sand and drilling them. Through apparently stereotyped behavior in the handling of prey, *P. reclusianus* always bores *O. biplicata* on the body whorl near the posterior end of the aperture (Plate 51, Figure 2). Boring the shell seems an extremely inefficient way to attack *Olivella*, whose operculum is a thin corneous scale. In fact, of 21 *O. biplicata* eaten in aquarium trials, only 4 were completely bored, 14 were incompletely bored, and 3 were unbored. Incompletely bored, empty *Olivella* shells are also taken in the field. Although *Polinices* may occasionally force its prey's operculum, the incomplete bore holes suggest another explanation, viz., that *O. biplicata* suffocates while wrapped in the predator's foot and relaxes. Since *Olivella* suffers no harm from being deeply withdrawn into its shell for 10 hours or more in response to osmotic stress (EDWARDS, 1965), this answer requires the snails be deprived of oxygen for lengthy periods. Moribund, but unbored, *O. biplicata* can be recovered from *P. reclusianus*. Since partially drilled, live snails also occur, escape is still possible after drilling begins. Probably the length of time the prey is enveloped in the predator's foot determines the mode of death.

Although *Olivella biplicata* often frees itself from *Polinices*' grasp, both the largest (28.4 mm) and smallest (17.0 mm) individuals available in feeding trials were eaten by the medium-sized *P. reclusianus*: neither was there any statistically significant difference between the

sizes of *Olivella* taken and those surviving, though sample sizes were inadequate (13 vs. 9 respectively). Other field and laboratory observations by N. Fotheringham (personal communication) and myself show olives of all sizes (10.4-28.4 mm) fall prey to *P. reclusianus*. Occasionally *O. biplicata* exhibits strong escape responses upon coming in contact with *Polinices* (see below).

Other gastropods may prey on *Olivella*. Larger olivids, though absent from the area under study, feed on *Olivella* species in Latin America (OLSSON, 1956). In the laboratory small *O. biplicata* are drilled (Plate 51, Figure 3) and eaten by *Acanthina spirata* (BLAINVILLE, 1832) (FOTHERINGHAM, 1966). These two species do not normally occur together in the field, *A. spirata* preferring rocky shores; but at more exposed sites *Olivella* are most abundant on sand near rocks and pilings where predators from solid substrates could attack them. *Jaton festivus* (HINDS, 1844), *Nassarius fossatus* (GOULD, 1849), and the opisthobranch *Navanax inermis* (COOPER, 1862) co-occur with *O. biplicata* and may eat it. No *Jaton* bore holes have been found in *Olivella* shells, however, and *Nassarius* is mainly a scavenger. *Navanax* proved unresponsive to *Olivella* in the field (Edwards) and in the laboratory (PAINE, 1963), and *O. biplicata* is not found in *Navanax* fecal pellets (PAINE, *op. cit.*).

FOTHERINGHAM (1966) has noted a distinctive bore hole on the columella of *Olivella* (Plate 51, Figure 4) and other gastropod shells. These shells were occupied by hermit crabs and were collected from rocky intertidal sites in the San Diego area. I have not found this marking on the shells of living *Olivella* or on hermit crab shells collected from subtidal sand bottom. The bore hole resembles those of gastropods, but may be made by a barnacle (TOMLINSON, 1953) or a flatworm (WOELKE, 1961). The much higher incidence of the bore holes in worn, encrusted "old" shells than in clean, "new" shells, though, suggests a non-predatory agent (Fotheringham, personal communication).

Asteroids commonly prey upon gastropods, and at least two eat *Olivella biplicata*. *Pisaster brevispinus* was occasionally observed taking these snails on the northern California and Oregon coasts. At Duxbury Reef (37°54'N Latitude), the only site where the two species co-occurred abundantly at low tide, ca. 40 seastars were examined; only one was feeding, taking an *Olivella* (22.7 mm) whose shell lip was damaged, possibly by a crab. These two species also live together near extreme low tide at Monterey Harbor and subtidally off North Spit at Coos Bay. *Olivella biplicata* shows a species-specific avoidance response to this seastar (see below).

The second asteroid predator on *Olivella biplicata*, *Astropecten armatus*, is more specialized for sand bottom life. The two species are commonly taken together in

southern California and Baja California, usually subtidally (Scripps Pier) but occasionally intertidally (Estero de Punta Banda, below Ensenada, Baja California). The feeding sequence was observed in an aquarium provided with fresh sand and running seawater. The seastar, apparently using distance chemoreception, quickly "runs" to and over an *O. biplicata* placed nearby and begins forcing its arms into the sand around the prey. While burying its arms, the seastar may shift laterally in the direction the snail was moving, or it may appear to carry or push the prey for a distance. *Astropecten* does not extrude its stomach but swallows prey whole. Even the largest *O. biplicata* do not gain safety through their size or strength: a 29.0 mm snail was readily taken and completely ingested in just over 2 minutes. During ingestion the predator's central disc may swell aborally and prey *Olivella* shells can be felt inside. Intraoral digestion may be an adjustment to life in sand or to the loss of suckers on the podia, or both; in any case, external examinations in the field will fail to reveal the foods of *Astropecten*. Although the shell of the 29.0 mm *Olivella* was still inside the seastar 23 hours after ingestion, in several aquarium trials an initially unfed *Astropecten* regularly ate > 1 adult snail per day over 4 - 5 days; and MACGINITTE & MACGINITTE (1949) report 3 or 4 snails (species unspecified) may be found at one time in an *Astropecten*. Clearly *Astropecten armatus*, to which *O. biplicata* shows no definite escape response (see below), could be an important predator upon *O. biplicata*.

Various crabs eat snails, either by cracking them open or by pulling them from their shells (see SHOUP, 1968, for references). Small *Cancer magister* DANA, 1852, which co-occurred with *Olivella biplicata* on several beaches in Oregon, ate live, though possibly moribund, *O. biplicata* in the laboratory. The crab held the snail with the legs of one side of its body, while reaching deeply into the shell aperture with the opposite cheliped. Considerable indirect field evidence - shells broken into many pieces (sometimes with all the fragments lying within a few square centimeters), empty shells with the body whorl alone broken away (Plate 51, Figure 5), occupied and empty shells with the lip broken back, and rare moribund snails with both the shell lip broken away and the foot torn raggedly - indicates crab predation on *O. biplicata*. Suspects include adult *Portunus xantusii* (STIMPSON, 1862), *Cancer antennarius* STIMPSON, 1856, and *Cancer magister*, all of which have been taken with *O. biplicata*. EBLING *et al.* (1964) found *Carcinus maenas* LINNAEUS, 1758, *Portunus puber* (LINNAEUS, 1767) and *Cancer pagurus* LINNAEUS, 1758, when kept in cages in the field with *Nucella lapillus* (LINNAEUS, 1758) (similar size range as *Olivella*), smashed and ate the snails as well as

removed others from their shells. Further, *Portunus puber* observed in the laboratory, used its master chelae to break away the body whorl of *Nucella*, producing shell damage like that observed in *Olivella* shells (Plate 51, Figure 5). Similarly, KOHN (1959) found xanthid crabs attacked *Conus* in the laboratory, breaking the outer lip of the snail's shells. These crabs never killed snails, though, probably because the latter could retreat into older, thicker portions of the shell. Clearly, then, crabs can and do produce the type of shell damage observed in *Olivella* shells.

Among vertebrates, gulls and other shore birds regularly forage in the sand at low tide, taking snails and other forms. *Olivella* is eaten by shore birds in northern Peru (KOEPECKE & KOEPECKE, 1952), and Stohler (personal communication) and I have observed gulls taking *O. biplicata* in California and Oregon, respectively. The gulls, probing irregularities in the sand, sometimes throw the snails out on the surface, and then overlook their find. All along the Pacific coast small *Olivella* shells can occasionally be found in the droppings of shore birds*. With the rising tide, on the other hand, fish, which are major predators on snails in some areas, move in large numbers over *Olivella*-rich sand flats and may well prey upon the snails, but this has not been observed. Purple dye substances irritating to fish are known for some olive shells (ABBOTT, 1954).

Probably the most important depredator on *Olivella biplicata* in accessible localities is man. Humans do not eat olive snails on our Pacific Coast, though they do in Brazil, where one species is locally called "vitela" (veal) or "vaquinha" (little cow) (MARCUS & MARCUS, 1959), and in Peru (OLSSON, 1956). *Olivella biplicata* shells were extensively traded by the American Indians, who used them as jewelry and money (STEARNS, 1889; HENDERSON, 1930; BAILY, 1935; GIFFORD & GIFFORD, 1942; and ABBOTT, 1954). Today the animals are collected in great numbers simply for the beauty of their shells. Shell dealers take them for sale at tourist stands across the country; some shells are made into earrings. A few West Coast residents also use *Olivella* to "decorate" furniture and to construct "artistic" shell mosaics. The protective shell has caused heavy losses for *O. biplicata*.

Thus, at low tide, *Olivella biplicata* are attacked by shore birds, especially gulls, and man; and, as the tide rises, they are preyed upon by seastars, octopuses, at least two species of gastropods, and probably by crabs and fish as well.

* REEDER (1951) also found *Olivella* in the stomach of a Marbled Godwit, *Limosa fedoa*, in southern California.

SPECIES-SPECIFIC PREDATOR AVOIDANCE RESPONSE

Various marine gastropods show specific escape reactions to predatory seastars and gastropods. The literature has been reviewed regularly (BULLOCK, 1953; PASSANO, 1957; KOHN, 1961; FEDER, 1963, 1967; MARGOLIN, 1964a; FEDER & CHRISTENSEN, 1966). Further work is available on herbivorous gastropods responding at a distance to carnivorous ones (see KOHN & WATERS, 1966, and references therein). The escape responses generally consist of rapid movement ("running," "galloping") away from the predator, sometimes with the shell being violently swung about, and occasionally accomplished by means of curious "leaping"; some naticids, *Haliotis rufescens* SWAINSON, 1822, and *Diodora aspera* (ESCHSCHOLTZ, 1833) extend a fold of the foot or mantle over their shells, preventing seastar tube foot adhesion (MARGOLIN, 1964a; MONTGOMERY, 1967). The stimulus is chemical and apparently emanates from the external epithelium of the predator, especially from the epidermis of tube feet (FEDER & LASKER, 1964). Contact with a single tube foot elicits vigorous escape reactions. Effective stimulation also occurs through distance chemoreception of whole animals and extracts.

Tests of escape responses in *Olivella biplicata* consisted of touching the snail's foot (propodium and parapodia) with isolated and intact tube feet from the seastars *Pisaster ochraceus*, *P. brevispinus*, and *Astropecten armatus*, as well as observing outcomes of contacts between whole animals. Controls consisted of similarly touching snails with a blunt probe or a glass rod. *Olivella biplicata* exhibited a vigorous avoidance response to contacts with *P. brevispinus* tube feet, but no greater reaction to *P. ochraceus* and *A. armatus* than to control treatments. The snails failed to give strong responses to contacts with the aboral surfaces of any of the three seastar species.

The minimum escape reaction of *Olivella biplicata* consists of a sharp turning away from the point of contact with *Pisaster brevispinus* or one of its tube feet, followed by top-speed crawling. More often upon contact *O. biplicata* rears up on the hind portion of its foot, withdrawing the propodium and throwing the parapodia forward; this response frequently flips the snails over backwards in a reverse half-somersault. In the extreme form of the response the animal, after throwing itself on its back, pumps the expanded metapodium up-and-down violently, lifting the snail from the substrate and carrying it away some 5 - 10 cm in a form of upside-down swimming. This metapodial swimming response is qualitatively distinct from any previously reported gastropod escape behavior. It is effected by holding the parapodia close to the sides

of the shell, especially at the anterior end, so the vigorous down beats of the large, horizontally extended metapodium force water down and back, lifting the gastropod and propelling it forward. After each of the more energetic responses the snails quickly right themselves and rapidly crawl a short way (ca. 8 - 12 cm) before resuming a normal pace. Escape movements, while carrying the animals away from the point of first contact with a whole seastar, may carry them up against another ray of the predator; in this case the avoidance reaction is repeated.

Initially *Olivella biplicata* gave no noticeable response to *Polinices reclusianus* in feeding trials, even crawling over the predator's propodia without reaction. Later in the trials, however, *Olivella* occasionally gave violent avoidance responses to contacts with *Polinices*, including the "swimming" response. Whether experience with the predator accounts for the appearance of the sporadic escape behavior is not known. *Olivella* also forces its way from the grasp of *Polinices* as described above.

Pisaster ochraceus is abundant on rocks and pilings projecting from beaches, but only occasionally ventures onto the sand; whereas, *P. brevispinus*, the species *Olivella biplicata* avoids, is a natural neighbor of and predator on *Olivella* (see above). Thus, the escape reaction is only elicited by the species of *Pisaster* that *O. biplicata* is likely to meet in the field, and the response appears to have direct survival value in carrying the snail away from a known predator. *Astropecten armatus*, on the other hand, lives with and eats *O. biplicata*, but elicits no definite avoidance response from it. Qualitative observations indicate *Astropecten* moves so quickly over sand that escape efforts by *O. biplicata*, including the "swimming" response with its slow start, would be futile and could not be selected for. Several *Astropecten* species can crawl 10 mm/sec (FEDER & CHRISTENSEN, 1966), which exceeds all but the fastest escape responses of gastropods (KOHN & WATERS, 1966).

Animals exhibiting avoidance responses show varying abilities to discriminate between possible predators. Two highly specific responses are pertinent to the case of *Olivella*. Appropriately for its rocky intertidal habitat and vulnerabilities, *Acmaea pelta* ESCHSCHOLTZ, 1833, shows a "running" escape response to *Pisaster ochraceus*, but not to *P. brevispinus* (MARGOLIN, 1964b) - the opposite reactions from those of *O. biplicata*. In contrast, *Dendroaster excentricus* ESCHSCHOLTZ, 1831, responds like *Olivella*, avoiding the predatory *P. brevispinus* by burrowing into the sand, while ignoring *Astropecten armatus* (MACGINNIE & MACGINNIE, 1949), even though the latter commonly feeds on sand dollars (E. W. Fager, personal communication). These differing responses could be used as bioassays in isolating the specific chemicals eliciting

avoidance reactions. Whether animals of the various taxa respond to the same or different chemicals is a question of particular interest; representatives of different phyla do respond to certain seastar extracts (FEDER & ARVIDSSON, 1967), and the substances in extracts of different seastars show chemical similarities (MACKIE *et al.*, 1968).

GONOR (1966), from a consideration of the escape responses of various prosobranchs, suggests these behavior patterns were not evolved *de novo*, but developed from pre-existing locomotory and righting mechanisms. In the case of *Olivella biplicata* the minimum avoidance response of rapid crawling does, but the more vigorous responses do not, appear to agree with this view. The "rearing" and "swimming" escape behavior has, however, other uses than predator avoidance: it is seen when, under conditions of crowding, one olive is bitten by another, or when a snail is placed in an alien environment, e. g., a plastic bag. The truly striking thing about *Olivella* is the dexterity and versatility with which it uses its foot — in locomotion, burrowing, handling of live prey, and in reproductive behavior. Perhaps a more intriguing, and resolvable, aspect of the development of avoidance responses concerns not the movements themselves but the acquisition of, and sensory mechanisms used in, the discrimination of substances from predators.

Various investigators have seen gastropod avoidance behavior succeed in permitting at least some individuals to escape predators (see FEDER, 1967; MARGOLIN, 1964a). FEDER (1963) found that snails exhibiting escape responses to *Pisaster ochraceus* were not fed upon in proportion to their abundance and availability, whereas mussels and barnacles were; the non-responding *Acmæa scabra* (GOULD, 1846), on the other hand, ranks high on the seastar's food list even though few live within the latter's range. The apparent rarity of captures of *Olivella biplicata* by *Pisaster brevispinus*, despite the abundance of both, was noted earlier. Defensive escape reactions, even if effective in only a limited percentage of predator contacts, would be of selective advantage to gastropods. Indeed, that these behavior patterns have evolved demonstrates both their adaptive value and, in turn, the effectiveness of asteroids as predators.

POPULATIONAL EFFECTS OF PREDATION

The significance of predation for *Olivella biplicata* populations can only be speculatively evaluated since available information is fragmentary. Probably larvae and newly metamorphosed young, vulnerable to a wider and different array of predators than adults and to fluctuations in physical factors as well, suffer heavy losses, though the evidence is circumstantial. Size frequency distributions obtained through quantitative sampling of natural populations at Coos Bay, Oregon, Yaquina Bay, Oregon, and Duxbury Reef, California (EDWARDS, unpubl.) show that, while new young are occasionally abundant, proportionally few reach reproductive size (over 16 mm). *Olivella* populations are often primarily composed of larger, slow-growing animals, which may live 10 years or more (P. W. Frank and D. C. Edwards, unpubl.; STOHLER, 1962, and personal communication). Yet, despite a potentially lengthy reproductive life during which increasing numbers of progeny are likely produced each year, even a medium-sized *Olivella* female (20.6 mm) produced 4 236 eggs in a single spawning period (EDWARDS, 1968). Also the species reproduces year-round (EDWARDS, *op. cit.*). Thus many young are spawned for even the low, though continuous, population turnover indicated. Numerous suspension feeders and small predators could, of course, take heavy tolls on the bottom-swimming larvae (EDWARDS, *op. cit.*) and newly settled young. In some species the escape responses of smaller animals to seastars are less successful than those of larger individuals (FEDER, 1967). Gulls and *Conus* also take small, immature *Olivella* (see above).

Although a variety of predators has been shown to attack adult *Olivella biplicata*, several factors mitigate their populational effects. First, the snails may evade predators. A species-specific avoidance response to *Pisaster brevispinus* was detailed above, and escape reactions to *Polinices reclusianus* were noted. In addition, larger *Olivella*, which live higher on the shore, tend to remain buried during bright light conditions (EDWARDS, 1965); and this behavior may aid in the avoidance of visual pred-

Explanation of Plate 51

Figure 1: *Olivella biplicata* shell (11 mm) bored by *Octopus* sp. (photograph by Ron Lam)

Figure 2: *Olivella biplicata* shell (22 mm) bored by *Polinices reclusianus* (photograph by Ron Lam)

Figure 3: *Olivella biplicata* shells (ca. 25 mm) with the body whorl broken back, possibly by crabs (photograph by John W. Evans)

Figure 4: *Olivella biplicata* shell (8 mm) bored by *Acanthina spirata* (photograph by Ron Lam)

Figure 5: *Olivella biplicata* shell (15 mm) with bore hole of unknown origin (photograph by Ron Lam)

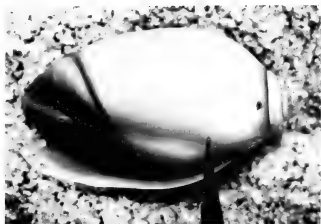


Figure 1

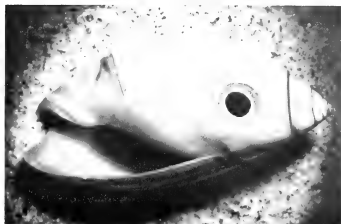


Figure 2

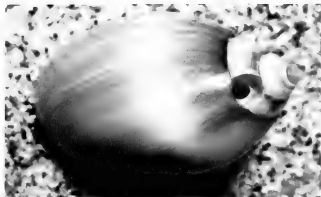


Figure 3



Figure 4



Figure 5



ators. Second, not all the predators attack *O. biplicata* in any given locality, e. g., *Conus californicus* and *Astropecten armatus* occur only in southern California, whereas *Cancer magister* and *Pisaster brevispinus* are more northerly species. Further, in the temperate latitudes under consideration predator food choices may vary seasonally and feeding may cease altogether in winter. But likely the main factor reducing predation on adults is their size: they have simply grown too large to be taken by small carnivores, e. g., various worms. Indeed the larger snails themselves prey on polychaetes (Edwards, unpubl.). Nonetheless, *Polinices*, *Astropecten*, and *Octopus* eat even the largest *Olivella*.

Since empty *Olivella* shells of different sizes probably do not disintegrate at very different rates, an unbiased collection of such shells would provide information on both size specific mortality rates and predation rates for predators that leave distinctive marks. Empty shells are always rare on *Olivella* beaches, so hermit crabs, *Holopagurus pilosus* HOLMES, 1900, were employed as collectors. (A difficulty here is that bored shells, which should afford less protection, may be selected against by the crabs.) E. W. Fager kindly provided me with an arbitrary sample of 130 *O. biplicata* shells from a large hermit crab aggregation in 18 feet of water at Scripps Pier. The size-frequency distribution of the shells (Text figure 1) shows a sharp decline in the abundance of larger ones: only 12 shells (9%) were of adult size (> 16 mm). Although the size structure of the La Jolla population is not known, the shell data suggest relatively high mortality among immature snails, but very low mortality among adults. Only 10 (7.7%) of the 130 *Olivella* shells gave

evidences of particular predators: 4 had *Polinices* bore holes, 4 had broken shell lips indicative of crab attacks, and 2 bore possible *Octopus* drill holes. Possibly *Polinices* and *Octopus* prefer larger prey, as half their marks fell among the few adult shells.

With the possible exception of man's destruction of snails in some localities, predation on adults is apparently not important in the regulation of *Olivella biplicata* populations, though losses among the more vulnerable young may well be crucial. In nearly 3 years of observations that included diving, only a few scattered cases of predation were observed. Neither is food availability likely limiting in this gregarious, omnivorous species (Edwards, unpubl.), at least not until great densities (> 130 per m^2 on bay beaches, over 700 per m^2 in lagoons) are attained, and here again the stress falls primarily on the very young (EDWARDS, 1965). *Olivella biplicata* populations are often heavily infected with parasitic trematodes (STEINMETZ, 1951; DUERR, 1965; EDWARDS, 1968; Ivan Pratt, personal communication), and well over 50% of adults may be unsexed by the infections (EDWARDS, 1968). Parasitic disease definitely reduces natality and could limit population sizes. Sporadic "disasters" may also kill many *Olivella*. Exceptional fresh water flooding and silting took heavy tolls in the San Diego Flood Control Channel in November, 1965; and similar threats arise periodically on the northern coast. Storms and winter sea turbulence — also tidal waves like that from the 1964 Alaska earthquake — produce shifts of beach sand, posing dangers of deep burial and transport out of suitable habitat. Whole beaches may be carried away in winter, and one storm (October, 1963) deposited 1-2 m of new sand on a Coos Bay, Oregon, beach, markedly reducing *O. biplicata* densities (EDWARDS, 1965). These erratic upsets eliminate snails, but probably occur too rarely and unpredictably to regulate densities or to account for the regular size-frequency structure of most *Olivella* populations. The size (\approx age) structure in *Olivella* populations, characterized by a preponderance of adults, probably results from high mortality among juveniles (and possibly reduced adult fecundities in parasitized populations) and excellent survivorship and individual longevity among adults; turnover of the breeding population is likely limited.

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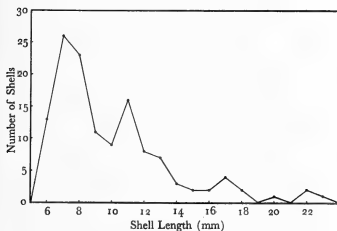


Figure 1

Size-frequency distribution of 130 *Olivella biplicata* shells from a *Holopagurus pilosus* aggregation at Scripps Pier

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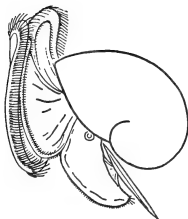
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Rediscovery of *Terebra cochlea* DESHAYES

BY

TWILA BRATCHER

8121 Mulholland Terrace, Hollywood, California 90046

(Plate 52)

IN 1857 DESHAYES DESCRIBED A SINGULAR and beautiful species of *Terebra* (*T. trochlea*) in the *Journal de Conchyliologie*, page 89, number 24 and illustrated on plates 5 and 6. This medium large species (holotype 65 mm \times 13 mm) of a soft fawn color is decorated with flammules of creamy white. The type locality was given as Zanzibar. Two specimens of the type lot from the Cuming collection are in the type collection of the British Museum (Natural History). These I examined and photographed. Deshayes also retained a specimen or specimens of the type lot in his own collection (École des Mines, Paris). In 1860 REEVE published an excellent figure of this species in his *Monograph of the genus Terebra*, in the *Proceedings of the Zoological Society of London* (species no. 54), though his description reverses the colors and lists the shell as whitish with fawn markings. In 1885 TRYON included it in the *Terebra* section of the *Manual of Conchology* (vol. 7, p. 16; plt. 12), and in 1888 PAETEL included it in the "Catalog der Conchylien Sammlung" (p. 255). He also included *T. cochlea* DESHAYES, type locality Zanzibar, which obviously was a misspelling for *T. trochlea*. For nearly a hundred years *T. trochlea* seems to have been dropped completely from molluscan literature, and since the type lot this species has not been reported from Zanzibar or any other locality.

In July 1967 Clifton S. Weaver of Hawaii sent me for examination a specimen of *Terebra* which matches the holotype of *T. trochlea*. This specimen was collected at Nukuhiva in the Marquesas by Richard Sixberry. At the convention of the American Malacological Union in 1968 at Corpus Christi, Texas, another specimen of this species was shown on a slide accompanying a paper by Dr. Harald Rehder of the United States National Museum, though at that time the *Terebra* was unidentified. This latter speci-

men (U. S. N. M. no. 679155) was collected by Richard Sixberry also at a depth of 20 feet in muddy sand at Taiohae Bay, Nukuhiva, Marquesas. The specimen is 65.3 mm \times 12.8 mm.

Though it is possible that this species occurs in the Zanzibar area, one must assume that, like many other species of *Terebra* described in early literature, the type locality is erroneous unless other specimens are reported from that area.

Description of the shell: Shell medium large; color fawn to light reddish brown with flammules of creamy white; whorls slightly convex and turreted, shouldered anterior to prominent convex subsutural band which is set off by well defined suture and broad, deeply impressed subsutural groove which is microscopically punctate in the early whorls; sculpture of early whorls of indistinct axial grooves and obsolete flat axial ribs which form small nodes at their posterior endings on both whorl and subsutural band; in later whorls axial grooves become numerous fine axial striations, but nodes continue to occur anterior to suture and subsutural groove; body whorl of medium length; aperture ovate; outer lip thin with color pattern showing through; columella white, heavy, quite straight; siphonal fasciole well defined, striate, set off by a sharp keel; anterior canal very broad, short, recurved.

ACKNOWLEDGMENTS

I wish to thank Dr. Harald A. Rehder of the Smithsonian Institution for the loan of the specimen of *Terebra trochlea* DESHAYES for study and photography. I also wish to thank Clifton S. Weaver for sending for my examination the specimen which brought this species to my attention.

Explanation of Plate 52

Terebra trochlea DESHAYES, 1857

Figure 1: Holotype and paratype, British Museum (Natural History); holotype on left.

Figures 2, 3, 4: Specimen no. 679155, in the United States National Museum.



Figure 1



Figure 2



Figure 3



Figure 4



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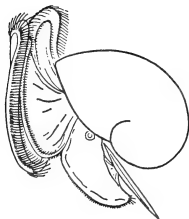
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Growth Characteristics of *Acmaea persona* ESCHSCHOLTZ¹

BY

RON KENNY

Zoology Department, University College of Townsville, Queensland, Australia
and

Marine Science Center, Oregon State University, Newport, Oregon 97365

(4 Text figures)

WILBUR & OWEN (1964) HAVE REVIEWED the literature on growth studies of mollusks and FRANK (1965a, 1965b) has discussed some aspects of growth for 3 species of *Acmaea* on the Pacific coast of North America.

Acmaea persona ESCHSCHOLTZ, 1833 has a geographic range from latitude 37° N to latitude 60° N on the Pacific coast of North America (FRITCHMAN, 1962). The vertical range of the species in the intertidal zone extends approximately from mean sea level to mean higher high water. Characteristically this limpet is found in

areas sheltered from the heaviest wave action, such as the heads of small bays (KENNY, in MS).

The specimens used in this study were collected at Boiler Bay and Yaquina Head near Newport, Oregon (lat. 44° N; long. 124° W) during the summer of 1967.

During the collecting period temperatures in the area ranged from 10° to 23° C (air), 8.5° to 16° C (sea), and 10.5° to 31° C (rock surface). January sea temperatures for the area range between 7.7° and 10.3° C (WYATT, STILL & HAAG, 1965) and the mean range of air temperatures for January is 3.4° to 9.7° C (U. S. Weather Bureau records).

No particular selection was exercised in collecting these limpets, but as the collections were made initially for physiological experiments, they are representative of size range rather than truly random collections. One hundred and eighty-nine limpets were collected and the analysis of annual growth rings is based on records from 166 individuals in which the rings were considered not to have been affected by erosion. Allometric growth data are based on measurements of approximately 100 limpets.

Measurements were taken of shell length, breadth and height (mm), shell weight (gm) and tissue weight (gm)

¹ Supported by U. S. Office of Naval Research, Project Number NR 104-936, "Marine Ecological Studies."

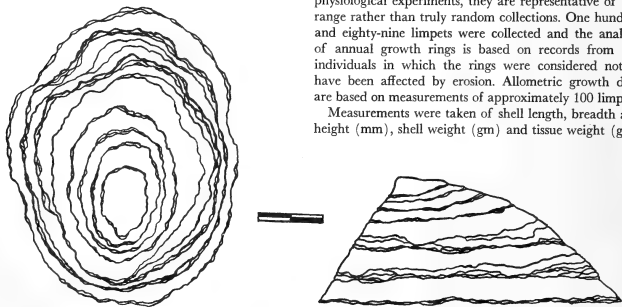


Figure 1

Dorsal and lateral views of *Acmaea persona*, length 44.4 mm,

after removal from the shell and surface drying with paper towelling. Shell volume (ml) was measured with distilled water containing liquid detergent, from graduated pipettes.

In analysis and graphical presentation all measurements have been related to shell length.

The step-like ridges on the shell surface are caused by differences in the rate of shell formation. As the result of observations in the field on a small number of marked animals, Dr. P. W. Frank has stated (personal communication) that these ridges are annual growth rings formed in winter (Figure 1). Further, within each annual step, fine, regularly arranged, secondary rings may be seen under magnification.

The measurements of shell length have been arranged in classes on the basis of number of annual rings and the size frequencies for these classes are shown in Figure 2. As the shell edge must be presumed to be forming part of the next annual ring, the age of the limpet is the annual ring number of years plus part of a year.

The number of animals in the 0 ring class is too small to warrant detailed analysis, but the samples for other classes show a mean annual increase in shell length of 6 mm in the second year, 4 mm in the third year, 4 mm in the fourth year, and 3 mm in the fifth year.

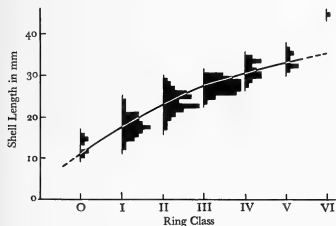


Figure 2

Frequency distribution of shell length related to number of annual showing annual rings; drawn from glass tracings. rings, for *Acmaea persona*.

As the largest specimen collected was 44.4 mm in length, it is probable that the life span is considerably longer than 6 years.

Counts of the number of secondary rings occurring on the surface of an annual growth area (both summer and winter sections of the step) were made from 55 individuals, with no surface erosion, ranging in shell length from 25.3 mm to 35.8 mm and showing 2, 3, or 4 annual rings. In each case the count was made on the area one step in from the shell edge, i. e. irrespective of age, for the same period of time. The number of rings recorded varied from 114 to 201 with a mean of 149.

The allometric patterns of growth for various shell dimensions and for the soft tissues are shown in Figures 3 and 4. Growth equations for these relationships are listed below, where L is shell length in mm, B is shell breadth in mm, H is shell height in mm, V is shell volume in ml, W is shell weight in gm, and wt is tissue weight in gm.

$$\begin{aligned} B &= 0.85 L - 1.2 \\ \log V &= 3.27(\log L) - 4.4 \\ \log wt &= 4(\log L) - 5.7 \end{aligned}$$

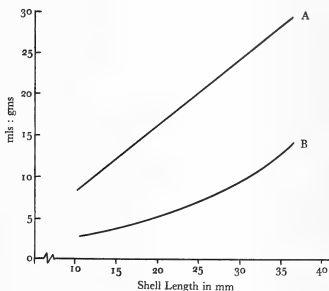


Figure 3

Relationship between shell length and shell breadth (A) and shell height (B), for *Acmaea persona*.

The relationships of shell height and shell weight to shell length are more complex and neither growth pattern can be described readily by a single mathematical formula throughout the range of shell lengths. The shell weight relationship can be expressed as two equations, one for small shells and a second for larger specimens, with the change of form taking place at lengths between 25 and 28 mm.

$$\log W = 2.7 (\log L) - 3.9 \quad (\text{small shells})$$

$$\log W = 5 (\log L) - 7.2 \quad (\text{large shells})$$

Similarly the shell height to length equation,

$$\log H = (\log L) - 0.6$$

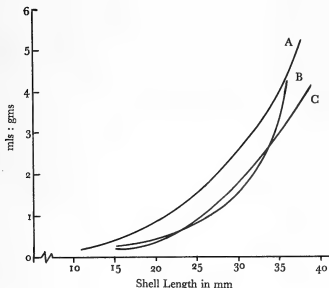


Figure 4

Relationship between shell length and shell volume (A), shell weight (B), and tissue weight (C), for *Acmaea persona*. The vertical scale represents millilitres for the shell volume graph, and milligrams for the shell weight and tissue weight graphs.

applies only to small shells and for shells longer than 25 mm, a single formula cannot be derived.

FRANK (1965a, 1965b), commenting on other species of *Acmaea* (*A. pelta* ESCHSCHOLTZ, 1833, *A. digitalis* ESCHSCHOLTZ, 1833, *A. paradigitalis* FRITCHMAN, 1960), has noted that due to the wide size range in any age class, size alone does not permit an estimate of either age or longevity. A similar statement would apply to *A. persona*.

HYMAN (1967) has combined the results of studies on *Patella vulgata* LINNAEUS, 1758 from English coasts by RUSSELL & ORTON to give size ranges for age classes of that species. Calculations from these data show *P. vulgata* having a 50% increase in length in the second year and a 28% increase in the third year, compared with corresponding figures of 36% and 16% for *Acmaea persona*.

The suggested probable life span of more than 6 years is similar to the "5 to 16 years" listed for *Patella vulgata* by HYMAN (*op. cit.*). COMFORT (1957) gives 15 years as the life span for *Acmaea dorsuosa* GOULD, 1859 and DARBY (1964) discussing a gastropod from the Oregon

coast, *Tegula funebris* (A. ADAMS, 1855), mentions individual specimens estimated to be 12 and 30 years old.

The graphs for length-breadth and length-height relationships are similar in form to those presented by HAMAI (1937) for *Patelloida grata* (GOULD, 1859). The increase in height of the shell in older specimens of *Acmaea persona* can be related to the change of direction of shell growth in older animals (see lateral view, Figure 1).

"Ledging" has been reported by MOORE (1934) in *Patella vulgata*. MOORE described this as a "temporary change in the angle of shell growth" and considered it to be due to slowing of shell formation during the winter. As noted above, FRANK has suggested a similar explanation for the formation of annual rings in *Acmaea persona* shells.

From the available data the overall winter range of environmental temperatures for *Acmaea persona* is 3.4° to 10.3° C and the overall summer range 8.5° to 31° C.

WILBUR & OWEN (1964) cite several studies showing direct relationships between growth rate of mollusks and environmental temperature. It seems probable that the annual differences in rate of shell growth in *Acmaea persona* are primarily related to seasonal differences in environmental temperatures in the intertidal zone.

The number of secondary rings developed in an annual growth area suggests the number of short term active growth periods in one year. The wide range recorded for *Acmaea persona* shows considerable individual variability in number of short term growth periods per annum. For an intertidal species, such as *A. persona*, this variability is probably influenced by several environmental factors (microclimate, tidal patterns, and wave action) as well as by physiological factors.

ACKNOWLEDGMENT

The author wishes to thank Dr. Joel W. Hedgpeth for the laboratory accommodation and facilities made available at the Oregon State University, Marine Science Center, Newport.

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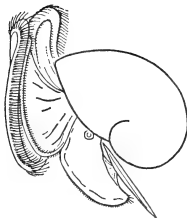
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Use of the Propodium as a Swimming Organ in an Ancillid

(Gastropoda : Olividae)

BY

BARRY R. WILSON

Western Australian Museum, Perth, Western Australia

(Plate 53; 1 Text figure)

AMONG THE PROSOBRANCH molluscs swimming as the prime method of locomotion is confined to the pelagic Heteropoda although there are reports that several members of the families Olividae and Naticidae are capable of brief "flights" of swimming activity.

D'ORBIGNY (1841, p. 418) observed this type of locomotion in *Oliva tehuelchana* (D'ORBIGNY, 1841), and OLSSON (1956, p. 161) mentioned the swimming ability of species of the genus *Olivella*. MARCUS & MARCUS (1959, p. 103) reported swimming in *Olivella verreauxii* (DUCROS, 1857). In all these cases the movement was effected by the lateral wing-like flaps of the metapodium which characteristically fold over and cover the shell in members of the Olividae. There are no details in these reports concerning the duration of the swimming activity or the circumstances in which it occurred.

ZIEGELMEIER (1958) reported swimming in the Mediterranean naticid *Polinices josephinus* (Risso, 1838). In this case the propodium is the propulsive organ. The animal "swims" in two positions. Most frequently it remains in the normal crawling position and the "whipping" of the propodium lifts the front end of the body off the sand and propels it forward. The posterior part of the foot remains in contact with the surface of the sand. Less commonly the animal twists into an upside-down position and the "whipping" of the propodium lifts the animal off the substrate and propels it forward a distance of 3 to 5 cm (in a large animal) for each stroke. Each propodium stroke is from the horizontal position upwards, almost as far as the anterior wall of the shell, and then downwards again to the original position, and lasts between 1 and 2 seconds. ZIEGELMEIER interpreted both forms of "swimming" behaviour as escape or "flight" reactions. It occurred when crawling animals were touched with a stick or when they collided with another animal.

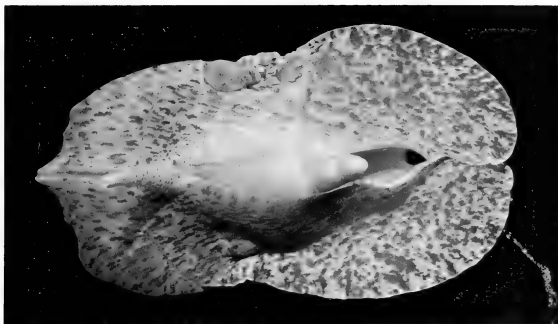
Similar behaviour by the ancillid *Ancillista cingulata* (SOWERBY, 1830) was observed on a recent field trip in the North-West of Western Australia. A single specimen

was collected in fairly coarse sand on an intertidal sand flat on the western side of Point Cloates (22° 43' S; 113° 40' E). It was crawling beneath the surface of the sand and left a long trail, wider than those of *Oliva ornata* MARRAT, 1870, which is common at the same place. The preserved body and the shell of the specimen are now in the collection of the Western Australian Museum (cat. no. 4902-68).

External Anatomy of *Ancillista cingulata*

Like other olivids, the foot of this specimen of *Ancillista cingulata* is divided by curved transverse grooves on both dorsal and ventral surfaces into a crescent-shaped anterior part, or propodium, and a posterior part, or metapodium. (For detailed structure of *Oliva*, *Olivella* and *Olivancillaria* see MARCUS & MARCUS, 1959). The anterior edge of the propodium does not have a deep horizontal groove as in *Oliva* and *Olivella* but there is a deep medial longitudinal groove from the anterior margin to the posterior margin on the dorsal surface. At its posterior end the metapodium is deeply forked, a characteristic of the subfamily Ancillarinae (see OLSSON, 1956, p. 169). The much reduced head is completely covered by the anterior ends of the lateral metapodial flaps, and is represented by only 2 small flap-like tentacles. There are no eyes. Beneath the right hand tentacle the small mouth is located. There is a very thin, elongate operculum carried on the dorsal surface of the metapodium medially, below the spire and concealed by the posterior ends of the lateral metapodial flaps.

In the fully extended crawling position (Plate 53) the foot was greatly expanded (approximately 9 cm long, 6 cm broad) and the length of the propodium was a little less than one quarter of the total foot length, i. e. rather larger than in other olivids. The lateral flaps of the metapodium covered the body whorl of the shell, except when the animal was disturbed, but they gaped around the spire so that that part of the shell was usually



A living specimen of *Ancillista cingulata* (SOWERBY, 1830),
collected at Point Cloates, Western Australia,
in the fully extended crawling position.



visible. The siphon was carried in an oblique-erect position. The body was white, flecked with pale grey and fawn.

Swimming Behavior of *Ancillista cingulata*

The animal made no attempt to burrow into a thin cover of sand which was put in the bottom of the dish of water. Its usual method of locomotion was rapid gliding aided by secretion from the anterior edge of the propodium of a thick mucous sheet which passed over the dorsal and ventral surfaces of the body. When the animal was agitated by prods with a pencil it suddenly threw itself into a series of violent contractions which carried it to the surface of the water and around the dish in a jerky, apparently random manner, reminiscent of the random swimming movement of scallops. The propodium repeatedly flapped backwards from the horizontal plane, first dorsally and then ventrally at regular intervals of slightly more than one second. Each movement threw the animal forward a distance varying be-

tween 5 and 15 cm. The ventral beat appeared to be the most effective. Most of the time the animal remained in the normal horizontal position with the shell uppermost, but "barrel-rolls" were frequent. This activity continued for 45 seconds, during which time the propodium flapped 35 times. The animal then sank to the bottom and resumed its crawling activity.

During the next 24 hours the same swimming response was observed several times, sometimes stimulated by agitation and sometimes occurring spontaneously. Each time the number of beats and the duration of the swimming period were about the same as before. Although the progress of the animal was erratic and confined within the dish, it is estimated that the total distance travelled in the open water during each burst of swimming activity would be about 3 meters.

The following day a thick layer of sand, an inch or so, was put in the dish and the animal buried itself and thereafter remained motionless with only the siphon tip visible. When dug out and agitated, it again responded by the swimming reaction with the same duration as before.

It seems most likely that this response is an escape reaction. The distance travelled and the erratic progress would allow the animal to evade most predators if this is its function. Observations on the locomotory behaviour of other ancillids which have a similarly broad propodium would be of interest. It is noteworthy that in the two unrelated families Naticidae and Olividae similar foot structure, i. e. division into propodium and metapodium, has been evolved independently, and that in each family at least one species has made use of the propodium as a swimming organ.

SUMMARY

A specimen of the ancillid *Ancillista cingulata* SOWERBY, collected at Point Cloates, Western Australia, was observed to swim by dorso-ventral flapping of its broad propodium. This behaviour is interpreted as an escape reaction.

ACKNOWLEDGMENTS

Dr D. J. G. Griffin of The Australian Museum and Miss Anne Paterson of the Western Australian Museum shared in this observation. Mrs Shirley Slack-Smith helped in the literature search for other records of swimming in prosobranchs and Mrs A. Neumann kindly translated Ziegelmeier's paper.

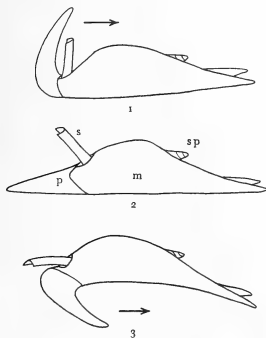


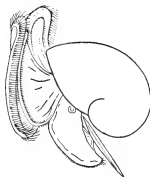
Figure 1

Diagram illustrating swimming movement by beating of the propodium in *Ancillista cingulata*.

p = propodium; m = metapodium; sp = shell spire; s = siphon.
1. dorsal stroke; 2. intermediate position (and crawling position);
3. ventral stroke.

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A New Genus and Two New Species of Typhinae from the Panamic Province

(Gastropoda : Muricidae)

BY

HELEN DuSHANE

Research Assistant, Invertebrate Zoology, Los Angeles County Museum of Natural History
Los Angeles, California 90007

(Plate 54)

IT SEEMS DESIRABLE to put on record the following undescribed forms of Typhinae. One is of a group previously not known in the Panamic province. In Typhinae, with a world wide range of distribution from the Eocene to the Recent, it is unusual to have in one's possession two new species to be described, one of them even requiring a new genus. Since KEEN's (1944) revision of the Typhinae, new interpretations of typhine morphology have been projected by FLEMING (1962) and VELLA (1961). However, until such time as workers have expressed their views in a proposed revisional work the author prefers to follow the outline presented by KEEN (*op. cit.*).

Cinclidotyphis DuSHANE, gen. nov.

(Plate 54, Figures 1 to 3)

Varices 4 per whorl; sculpture of numerous axial riblets and fine, raised spiral cords that are continuous across the varices and interspaces; tubes folded back, not forming vertical ribs; cancellate sculpture distinctive and unlike that in all other species of Typhinae.

Type Species: *Cinclidotyphis myrae* DuSHANE, spec. nov.

Cinclidotyphis myrae DuSHANE, spec. nov.

(Plate 54, Figures 1 to 3)

Shell small, fusiform, color dingy white, protoconch white (nuclear whorl worn off in holotype), followed by 4 subsequent whorls; shoulder narrow, sloping, not deeply channeled between whorls; varices 4 per whorl, each a rounded fold which extends above shoulder to join preceding varix; tubes folded back, not forming vertical ribs,

each with a suture on the anterior surface which is carried horizontally onto face of succeeding varix; varices with prominent spiral and axial sculpture producing a beaded effect at the junction, about 22 spiral cords on the last whorl; every other cord at the middle of the body whorl being smaller; 18 axial ribs on the body whorl at a line with the top of the aperture; aperture oval elongate and set off by a raised margin; lip narrow and crenulated; anterior canal open, narrowing toward the base with a slight dorsal curve; operculum lacking in type.

Type Material: The holotype is on deposit in the Los Angeles County Museum of Natural History, Invertebrate Zoology Type collection, catalogue number 1194.

Type Locality: The holotype was collected by the author at Tenacatita Bay, Jalisco, Mexico, January 25, 1968, among rocks near a sand beach; Lat. 19°16'50"N; Long. 104°48'27"W. It is the only specimen known.

Dimensions: Height 13 mm; maximum diameter 6.5 mm.

Discussion: The appearance of this shell in the Panamic province is all the more remarkable because of the paucity of world wide material in the nearest related genus, *Siphonochelus*. The largest concentration of species of this genus occurs in the Tertiary of Europe with the earliest known species *S. parisiensis* (D'ORBIGNY, 1850) dating back to the Middle Eocene according to KEEN & CAMPBELL (1964). The genus is represented in the Australian fauna with 5 species and in the Japanese fauna with 2, but up to the present time no specimens of this genus have been reported from the Panamic province.

The Mexican specimen differs from those in the genus *Pterotyphis* by having more than 3 tubes per whorl and in having finer sculpture. It has weak varices as in *Siphonochelus*, with 4 tubes per whorl. The cancellate sculpture is unlike that in all species of *Siphonochelus*. The open canal is distinctive. Perhaps it is closed in some

part of the growth cycle, but one would have to have more material to be certain. Another peculiar feature is the manner in which the tubes seem to have been folded back, not forming vertical ribs.

This species is named in honor of Dr. A. Myra Keen whose ready help is always a boon to the worker.

Pterotyphis (Tripterotyphis) arcana DuSHANE, spec. nov.
(Plate 54, Figures 4 to 6)

Shell small, base and tubes ivory white, body whorl brown with blotches of brown on earlier whorls, whorls 5 to 6, nuclear whorls two in number, rounded, smooth; adult sculpture developed in first postnuclear whorl, the third with the first tube; varices 3 per whorl, the upper end of each varix left open as a tube; tube openings elevated and at tips of spine; outer face of body whorl with 2 strong white spiral ribs riding over the varices; aperture oval, outer lip with a wide sinuous margin, reflected against the ends of 6 to 10 spiral ribs, smooth within; anterior canal sealed except at end; pillar with remnants of 2 previous canals.

Type Material: The holotype is on deposit in the Los Angeles County Museum of Natural History, Invertebrate Zoology Type Collection, catalogue number 1195; 2 paratypes, DuShane collection.

Type Locality: Mazatlan, Sinaloa, Mexico; Lat. 23°11'N, Long. 106°26'W. The 3 specimens were collected by the author on a rocky reef, February 24, 1968.

Two additional specimens from Banderas Bay, collected in January 1969 by J. DuShane indicate that the range of this species extends at least as far as 275 miles south of the type locality.

Dimensions: Holotype, height 15 mm, maximum diameter 8 mm, length of aperture 3.2 mm; Paratype 1, height 16

mm, diameter 8.5 mm; Paratype 2, height 14 mm, diameter 7 mm.

Discussion: Unlike *Pterotyphis (Tripterotyphis) fayae* KEEN & CAMPBELL, 1964, which is sculptured with about 22 spiral ribs, specimens of the new taxon have 2 major cords or ribs on the body whorl. Also, the brown coloration is less diffused on *P. (T.) arcana*. It differs from *P. (T.) lowei* PILSBRY, 1931 of the West Central American coast, by being easily separable on the basis of the 2 major ribs and the remnants of 2 previous canals; *P. (T.) lowei* has 3.

The earliest fossil record seems to be in the Miocene of Europe. Recent species occur in the Caribbean, Panamic, and Gulf of California areas.

ACKNOWLEDGMENTS

I am grateful to Dr. A. Myra Keen for her encouragement in suggesting that specimens of this importance should be reported, and to Dr. Bruce Campbell for his critical reading of the manuscript. Photographs are by Mr. Perfecto Mary, Stanford University.

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Explanation of Plate 54

- Figure 1: *Cinclidotyphis myrae* DuSHANE, gen. nov., spec. nov. Ventral view of holotype, LACM, Invertebrate Zoology Type Collection, catalog number 1194 (X4)
Figure 2: Lateral view of the holotype
Figure 3: Apical view of the holotype

- Figure 4: *Pterotyphis (Tripterotyphis) arcana* DuSHANE, spec. nov. Ventral view of holotype, LACM, Invertebrate Zoology Type Collection, catalog number 1195 (X4)
Figure 5: Lateral view of the holotype
Figure 6: Apical view of the holotype

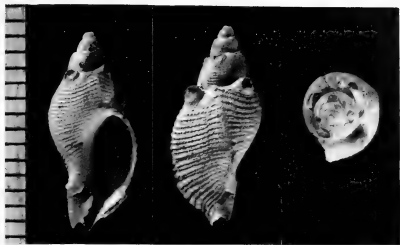


Figure 1.

Figure 2

Figure 3

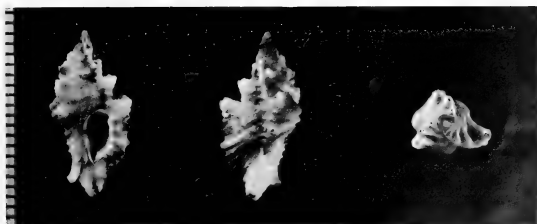


Figure 4

Figure 6

Figure 5



Gross Anatomy and Classification of the Commensal Gastropod, *Caledoniella montrouzieri* SOUVERBIE, 1869

BY

JOSEPH ROSEWATER

Division of Mollusks, U. S. National Museum, Washington, D. C. 20560

(Plate 55; 4 Text figures)

SPECIMENS OF A COMMENSAL GASTROPOD were reported by MANNING (1968) on two species of *Gonodactylus* (Crustacea: Stomatopoda) from the southwest Indian Ocean. Upon examination these were found to be *Caledoniella montrouzieri* SOUVERBIE, 1869, originally described from New Caledonia, a species whose anatomy was virtually unknown and whose systematic relationships are poorly understood. In the present paper an attempt is made to describe the gross anatomy of this species, comment on its supposed habits and to suggest for it a familial allocation.

HISTORICAL

The monotypic genus *Caledoniella* was described briefly by SOUVERBIE (1869) with *C. montrouzieri* as its only contained species. In the following year SOUVERBIE & MONTROUZIER (1870) supplemented the original description and published a figure of the shell, commenting that the animal had been found living on the thoracic appendages of *Gonodactylus*. They made no assignment of the taxon to a higher category. TRYON (1886) assigned the species to the subfamily Lamelliariinae of his family Naticidae with some doubt because the animal was unknown. As noted by ALLAN (1936), BASEDOW (1905) described a second supposed species of *Caledoniella* which subsequently has been found not to belong to that genus. PRESTON (1912) described *Episthe gonodactyli* from the Persian Gulf and Andaman Islands, and it is now considered to be an absolute synonym of *C. montrouzieri*. He gave the first sketchy description of the animal, but

did not assign it to a family. ALLAN (*op. cit.*) reported specimens of *Caledoniella* attached to a *Gonodactylus* from Albany Passage, Cape York, Queensland. In all probability these are *C. montrouzieri* (see Text figure 1).

Latest attempts at suprageneric classification of *Caledoniella* are those of THIELE (1929) and WENZ (1940). THIELE placed it in the Superfamily Lamelliariacea, subfamily Lamelliariinae and described a radula (see below under *Radula*). The assignment quite probably was made on the basis of shell shape since *Caledoniella* resembles *Lamellaria*. WENZ placed it in the Superfamily Pyramidellacea, Family Stiliferidae, probably because of the commensal relationship with *Gonodactylus*.

HOLTHUIS (1951) reviewed the known information relating to the geographic occurrence of *Caledoniella montrouzieri* and mentioned the presence of gastropod egg-capsules on the ventral surface of several of its host *Gonodactylus*. The same author (1941) figured similar egg-capsules and suggested that they were probably those of *Episthe* (= *Caledoniella*; see Text figure 4).

ACKNOWLEDGMENTS

I express my appreciation to Raymond B. Manning for calling to my attention the specimens of gastropods upon which this paper is based and to both him and L. B. Holthuis for discussing the relationship with *Gonodactylus*. I am also grateful to Mrs. Carolyn Bartlett Gast for preparing the plate illustrating animal and shells of *Caledoniella montrouzieri*. Ideas and interpretations are mine alone and I accept full responsibility for them.

EXTERNAL ANATOMY

Material:

	Shell		Locality	
	H'	W'		
1. Male	2.6	4.3	Anjouan Id., Comoro Ids.	USNM 679176
(Plate 55, Figs. A - F)				
2. Female	2.8	5.2	Anjouan Id., Comoro Ids.	USNM 679176
(not figured)				
3. Male	1.4	2.2	Tulear, Madagascar	USNM 679177
(Plate 55, Figs. G - I)				
4. Female	2.8	4.6	Tulear, Madagascar	USNM 678177
(Plate 55, Figs. J - L)				

H' = height in mm; W' = width in mm

The male animal from Anjouan, Comoro Islands, was used mainly for the following description and accompanying Plate. The three other available specimens were compared and found to agree.

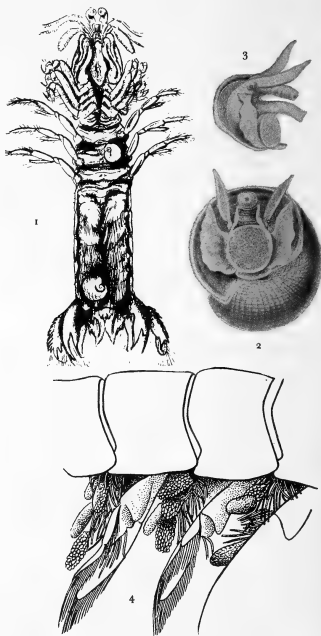
Foot: PRESTON'S (1912) description, although brief, characterized the foot and its epipodial fringe. He described the foot as an "adhesive organ", and this may be the case (see Plate 55, Figure C). The ventral surface of the foot (mesopodium) is disklike, and in one of the specimens examined was covered with a thin, chitinous "epidermis" which may be secreted for attachment to the host. Attachment is here not considered to be permanent, as evidence gained from a specimen examined *in situ* indicates these gastropods move about on the host (see **Reproduction**). At the anterior edge of the foot there is a groove which ascends dorsally to the base of the propodium.

"Epipodial Fringe": As described by PRESTON (1912) there occurs dorsal to the foot-disk, laterally and posteriorly, a foliated (in preserved specimens) fringe of tissue which he termed the "epipodial fringe" (Plate 55, Figures A to C). This structure appears to be the metapodium. Its function in living *Caledoniella* has not been reported, but may be analogous to that in *Natica* (FRETTER & GRAHAM, 1962, fig. 304) in partially covering the shell. A somewhat similar metapodial fringe was described and figured by QUOY & GAIMARD (1832, 1833) and by BERGH (1896) in *Vanikoro cancellata* (LAMARCK, 1822) (see ROBERTSON, 1962 and Text figures 2, 3).

An operculum was not observed in *Caledoniella mont-rouzieri*. It is probable that the operculum has been lost during the evolution of the species in connection with its adaptation to existence as a commensal.

Propodium: Located antero-medially above the anterior edge of the foot and between the anterior edges of the "epipodial fringe" there is a partially bilobed structure

which was dorso-ventrally folded in the preserved animal (Plate 55, Figures A to C). This is the propodium. When unfolded (Figure A), it forms a structure which appears to be highly utilitarian. YONGE (1953) has suggested that in *Hipponix antiquatus* (LINNAEUS, 1767) the propodium may be concerned with egg-capsule attachment. He did not mention the structure in males of *H. antiquatus*, although it may be shown in the figure of a male (see



Figures 1 to 4

YONGE, 1960, fig. 1). It is well developed in both male and female *Caledoniella montrouzieri*. Since it is probable that only the female takes part in egg-mass deposition, the presence of the propodium in males may signify protandry, or the structure may have some additional function, such as in feeding.

Proboscis: A prominent, muscular and extensible proboscis is present above the propodium with the mouth as a vertical slit at its extremity.

Radula: A radula was not found, although three of the animals were dissected in search of that structure. The only known report of a radula in *Caledoniella montrouzieri* is that of THIELE (1929): "Mittelplatte der Radula rundlich quadratisch, Schneide breit dreieckig, jederseits mit einigen Zähnen, Zwischenplatte mäßig groß, Schneide spitz, mit einer inneren Nebenzacke, die beiden Seitenplatten mit einfachen hakenförmigen Spitzen." Unfortunately the radula was not figured, and THIELE's description contains no clue to the relationships of *Caledoniella*. I am somewhat confused by the absence of a radula in the specimens examined by me and am led to question THIELE's report until it is confirmed.

Tentacles: A pair of fleshy tentacles is located above the proboscis. Due to preservation it is difficult to be certain how extensible these may be in the living animal, but they are relatively long. Tentacles are joined by a connecting lobe between their bases. The eyes occur as black-pigmented spots buried within the semitransparent tissue of the tentacles and are located somewhat toward the outer edges of their bases. Similar eyes have been reported in *Vanikoro* (BERGH, 1896) and in *Natica* (FRETTER & GRAHAM, 1962).

Penis: The penis, located near the base of the right tentacle, is long and slender in the two male specimens examined (see Plate 55, Figures A to C). It is simple (i. e., unbranched) and semitransparent; there is a closed gonoduct passing through its tissue.

Mantle and Mantle Cavity: In the illustration (Plate 55, Figures A to C) the mantle edge is rolled back to reveal the animal's tentacles, eyes and penis. The mantle edge is grayish-white in color and somewhat thickened; behind the edge the outside of the mantle is darkly pigmented, the dark color showing through the transparent shell; it is semitransparent and thin in the region of the ctenidia. The ctenidia are not excessively developed, nor is the mantle cavity extremely large.

Shell: There is evidence of sexual dimorphism in the shells of male and female specimens, especially in size. All are wider than long. In shells of male *Caledoniella montrouzieri* (Plate 55, Figures D-I) the body whorl is by far the major constituent and the spire consists of the protoconch and only about one subsequent whorl. Shell color

is pale yellowish-white and there is a shiny darker yellow periostracum which becomes deciduous upon drying. Sculpture is limited to fine, irregular axial lines of growth. The columellar lip may be roughly formed and rather deeply concave. Columellar muscle scar is elongate-oval, large and well defined; it is clearly visible within the aperture on inner wall of outer lip near posterior junction of outer lip and columella. The name "columellar muscle scar" in *C. montrouzieri* is somewhat a misnomer, as it is not altogether located on the columella! The muscle probably performs the same function as in other prosobranchs, that of pulling the animal into its shell.

In the female shell (Plate 55, Figures J to L) the spire of the specimen from Tulear is definitely lifted above the posterior limit of the aperture. There are about 3 whorls present, but the columella is considerably shorter. A small columellar muscle scar is visible within the aperture in a position similar to that in the male specimen. The shell is very narrowly umbilicate, while in the males there is no umbilical opening. The shell of the female from Anjouan is much the same as that of the male, but larger.

Protoconch: The protoconch in the two male specimens available for study is unsculptured, smoothly rounded and hardly raised, consisting of about $1\frac{1}{2}$ whorls. There is a sharp change in sculpture between protoconch and adult shell, the latter being defined by the beginning of the fine growth lines (Plate 55, Figures D, G). The female protoconch differs only in being partly covered by the adult shell, a phenomenon possibly related to sexual dimorphism.

GEOGRAPHICAL DISTRIBUTION

Distributional data accumulated to date indicate a rather extensive range for *Caledoniella montrouzieri* from the western Indian Ocean through the East Indies to western Polynesia in the tropical Indo-Pacific. Until recently the gastropod was reported only on *Gonodactylus chiragra* or *Gonodactylus* "species." MANNING (1968) has distinguished two additional host species. It is apparent, therefore, that the relationship is not specific so far as the species of *Gonodactylus* is concerned.

Locality Records: Persian Gulf (PRESTON, 1912; on *Gonodactylus chiragra* (FABRICIUS)). Comoro Islands: Anjouan Island (MANNING, 1968; on *G. platysoma* WOOD-MASON). Madagascar: Tulear (MANNING, 1968; on *G. smithii* POCOCK). Andaman Islands (PRESTON, 1912; on *G. chiragra*). Australia: Albany Passage, Cape York, Queensland (ALLAN, 1936; *Gonodactylus* sp.). In-

donesia: Amboina (HOLTHUIS, 1941; *G. chiragra*). New Caledonia: Art Island (SOUVERBIE, 1869; SOUVERBIE & MONTROUZIER, 1870; *Gonodactylus* sp.). Samoa: Mata-pao, Savaii (HOLTHUIS, 1951; *G. chiragra*).

REPRODUCTION

YONGE (1953, 1960) has discussed the problems associated with reproduction in a sedentary gastropod. He demonstrated how in *Hipponix antiquatus*, a species which lives permanently attached to hard substrates, and in which protandric hermaphroditism is the apparent condition, fertilization is probably effected by individuals of the male phase extending the long penis to the mantle cavity and oviduct of an adjacent female. YONGE suggested that, although sedentary, these gastropods occurred in sufficient density to make feasible such an arrangement for the adequate perpetuation of the species.

Available data indicate that *Caledoniella montrouzieri* always lives on *Gonodactylus*; at least none has been reported in any other habitat. Information concerning placement of the gastropod on its host seems to indicate a trend. More than one *Caledoniella* per *Gonodactylus* has been reported in the literature 4 times: (1) by ALLAN (1936), (2) by HOLTHUIS (1941, 1951 same case), and (3, 4) by MANNING (1968, specimens described and figured here). In three of these cases the larger of the two gastropods, here believed to be female, was located near the ventral posterior end of the crustaceans' abdomen between the pleopods; the smaller gastropod, believed to be male, was always located near the ventral posterior end of the thorax, between the pleopods. In the fourth case, MANNING (1968) found two gastropods between the pleopods of *G. platysoma*. Of the last two specimens reported, only one, a male (Plate 55, Figures A to F), was transmitted to me for study initially. It was located on the *Gonodactylus* on the posterior surface of the first right pleopod, and the place of attachment was later noted to be marked on the pleopod by a mucoid deposit with the outline of the foot. The second specimen was not removed from the *Gonodactylus* and was not received for examination by me until much of the present paper had been written. It caused a change in certain of the concepts I had formed concerning the permanency of attachment to the host.

The specimen, a female, was located between the fourth and fifth pleopods on the right side of the ventral posterior abdomen of *Gonodactylus platysoma*. It did not appear to be attached by its foot to the host, but rather was very firmly grasping a single gill filament of the *Gonodactylus* between the lobes of its propodium. It

is probable that the foot attachment was disturbed during collection or preservation. The animal probably was attached by its foot to the broad anterior surface of the fifth pleopod.

In all cases reported, therefore, of a male and female occurring together on *Gonodactylus*, the male shows a tendency to be located on the posterior thorax or in the last case, the anterior abdomen. The females have been found on the posterior abdomen. The following information concerning distribution of egg-masses indicates that it is most probable that the female, at least, moves about and is not sessile.

Egg-Masses: HOLTHUIS (1941) mentioned and figured egg-masses, supposedly those of *Caledoniella montrouzieri*, on the abdominal pleopods of specimens of *Gonodactylus chiragra* from the Moluccas and from Samoa (see Text figure 4, from HOLTHUIS, 1941). The egg-masses are similar to those described and figured by YONGE (1953, fig. 8) in *Hipponix antiquatus* except that *C. montrouzieri* deposits its masses outside of its own mantle cavity. Eleven masses are shown by HOLTHUIS to be attached over an area comprising about 3 abdominal segments.

The specimen of *Gonodactylus platysoma* from Anjouan Island had distributed over its abdominal segments a total of 35 egg-masses. These were attached to the more medial gill filaments of all but the first pair of pleopods. Their distribution was as follows:

	Left	Right
Pleopod Number 1	0	0
Pleopod Number 2	3	4
Pleopod Number 3	3	7
Pleopod Number 4	6	7
Pleopod Number 5	4	1
Total	16	19 = 35

Eggs within the capsules were in all stages of development. Some capsules contained material having no definite form, others contained fully formed young snails whose shells, consisting of about 1 whorl, resembled the protoconchs of the adults; several of the capsules were empty and evidenced terminal apertures through which the young may have escaped. Considering the advanced stage of development of the young in several of the capsules it is almost certain that when hatched from the capsules they are already at the crawling stage. The large number of capsules, together with their widespread placement on the host, would indicate the female moves about over the surface of the pleopods during their deposition. It is most probable that fertilization takes place when the female approaches the position of the male in



Through an oversight, the explanations to the Text figures and the Plate figures were omitted in our April issue of Volume 11. We apologize to the author, Dr. Joseph Rosewater, as well as to our readers.

Explanation of the Text figures
(see page 346)

Figure 1: *Caledoniella montrouzieri* on ventral side of *Gonodactylus* sp. from Albany Passage, Cape York, Queensland; note supposed male on thorax, female on posterior abdomen (from ALLAN, 1936, plt. 26, fig. 1).

Figures 2 and 3: *Vanikoro cancellata* LAMARCK; two views of animal; Figure 2, animal in aperture of shell, showing circular foot, propodium, epipodial fringe, operculum, proboscis, tentacles and eyes; Figure 3, animal withdrawn from shell and viewed from side (from QUOY & GAIMARD, Atlas, 1833, plt. 66 (bis), figs. 20, 21).

Figure 4: Egg-masses of *Caledoniella montrouzieri* on abdominal appendages of *Gonodactylus chiragra* (from HOLTHUIS, 1941, fig. 7).

Explanation of Plate 55

Figures A to F: *Caledoniella montrouzieri*, male from Anjouan Island, Comoros Islands.

Figures A to C: Front and side views showing propodium, foot, "epipodial fringe", proboscis, tentacles and penis.

Figure D: Enlarged view of protoconch.

Figures E and F: Two views of shell.

Figures G to I: Shell of male from Tulcar, Madagascar.

Figures J to L: Shell of female from same locality.

(scale represents 1 mm; detail squares are 0.75 mm)



A

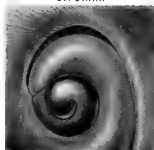


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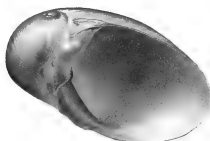
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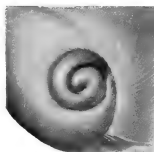
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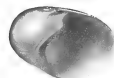


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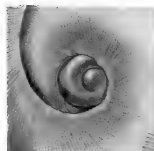


H

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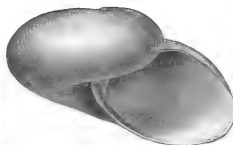
I



J



K



L



its location anterior on the host, although it has not yet been proven satisfactorily that the male is completely sedentary.

As mentioned by YONGE for *Hipponix*, the propodium, well developed in *Caledoniella montrouzieri*, probably plays an active role in egg-mass formation and deposition.

It was mentioned above that the female specimen of *Caledoniella montrouzieri* which was found *in situ* on *Gonodactylus platysoma* was grasping between the lobes of its propodium a single gill filament of the stomatopod. All of the 35 egg-capsules observed on the stomatopod were fastened to it by means of the capsules having incorporated along one edge 1 or 2 gill filaments. When the propodium was examined, its "pouch" was found to be lined with material very much resembling that which forms the egg-capsules. These items of circumstantial evidence leave the strong impression that the propodium is directly involved in egg-mass formation, that its intrinsic secretions form the egg-capsule around eggs transported from the female gonoduct, and that the lobes of the propodium also manipulate the *Gonodactylus*' gill filaments and incorporate them into the capsules. The groove running from the base of the foot to the propodium also appears to enter into this process.

FEEDING

Little real information is available regarding the feeding habits of *Caledoniella montrouzieri* except in a negative sense. Ctenidia do not appear to be developed for ciliary feeding, nor were a radula or jaws found, contrary to THIELE's (1929) description. A hint to the possible food of this species was extrapolated from observations made during the examination of the female specimen attached to *Gonodactylus platysoma* (see Reproduction). It was noted that numerous gill filaments were damaged at their tips and showed evidence of subsequent repair. Damage may have resulted from other causes or have been caused during egg-laying, although filaments were involved other than those to which capsules were attached. It is possible that the gastropod manipulates the gill filaments with the propodium (a well-developed propodium is also present in males), removes the tips of the filaments (just how this is done would be difficult to explain in the apparent absence of jaws or a radula; perhaps by chemical means), and "sucks" the body fluids of the host with its well-developed proboscis. If this is the case, the stomatopod-gastropod relationship should be termed a host-parasite one rather than a commensal one. If this theory proves invalid, the species also may feed on detritus or remnants of the food of its host. Direct

observation of the living animals is needed to settle this question.

CLASSIFICATION

The previous assignments to family group of *Caledoniella montrouzieri* by TRYON and THIELE (Lamellarinae) and by WENZ (Stiliferidae) are considered erroneous. In spite of the lack of a radula in present material, resemblance of the animal features to both *Vanikoro* and *Hipponix*, and of egg-laying habits to *Hipponix*, suggest placement in the Superfamily Hipponicacea (see TAYLOR & SOHL, 1962). As *Caledoniella* does not appear clearly to belong in either the Vanikoridae or Hipponicidae, however, a new family is proposed here:

Family Caledoniellidae, new family

Type Genus: *Caledoniella* SOUVERBIE, 1869, monotypic.

Diagnosis: The family concept is based on the characteristics of the type genus, in turn essentially those of its type species *Caledoniella montrouzieri*.

Further study may uncover evidence which will change this concept, but at present this placement seems to be the most logical for the species. The chance that *Caledoniellidae* belongs in Calyptraeacea seems more remote as animal resemblances are not so great (YONGE, 1938).

SUMMARY

Caledoniella montrouzieri is a reduced-spirally-coiled mesogastropod which lives on species of the stomatopod crustacean *Gonodactylus* throughout the tropical Indo-Pacific.

The animal is adapted for its commensal existence by possessing a "sucker-like" foot. A fringe-like metapodium probably partially covers over the shell in life. A well-developed propodium below the proboscis serves in the formation and attachment of egg-masses and probably is involved in feeding activities.

Placement of male gastropods on terminal thoracic or anterior abdominal and of females on posterior abdominal segments of *Gonodactylus* indicates a possible preference of these loci as habitats, although the female, at least, moves about on the abdomen of the host during egg-laying and probably feeding activities.

The family Caledoniellidae is proposed for *Caledoniella montrouzieri* and the group is assigned to the superfamily Hipponicacea with which it shows strongest relationship.

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A Preliminary Survey of Mollusks for Consag Rock and Adjacent Areas, Gulf of California, Mexico

BY

HELEN DUSHANE¹

AND

ELLEN BRENNAN²

(1 Map)

INTRODUCTION

CONSAG ROCK, GULF OF CALIFORNIA, MEXICO is at Latitude 31°07'N, Longitude 114°27'W in the extreme upper reaches of the Gulf of California, east by north of San Felipe Bay, offshore approximately 20 miles. As far as we have been able to determine, no extensive collecting of mollusks has been done in the waters surrounding Consag Rock. For this reason we consider it desirable to publish the results of a 3-day trawling expedition in this and the immediately adjacent areas.

The list of mollusks which follows is based on the results of a joint trip made by the authors and other individuals on June 27, 28, and 29, 1968 during which 217 species were collected. The trip was organized primarily for members of the Conchological Club of Southern California by Ellen Brennan. The following persons have made their collections from this trip available to us: Twila Bratcher, Don Cadien, Billee Dilworth, Joseph DuShane, William and Joyce Gemmell, Roy Poorman, William E. Viney, Erwin and Gertrude Wahrenbrock.

The nudibranch fauna of the Panamic province is only recently becoming better known through the efforts of FARMER (1963, 1966, 1967), LANCE (1961, 1966, 1968), and MARCUS (1967). Therefore, a determined effort was made by Don Cadien of the Los Angeles County Museum of Natural History to collect representatives of this group of animals and to transport them back alive.

Some of the other areas in the Gulf of California have been rather extensively explored over a period of years

by the California Academy of Sciences (1888 - 1921), the *Velero* III of the Allan Hancock Foundation (1931 to 1941), and the Puritan - American Museum of Natural History Expedition (1958). Poorman dredged mollusks over a period of years (1961 - 1967) in the areas of San Carlos and Bacochibampo Bays, Guaymas, Sonora, Mexico. The specimens collected have been reported (DUSHANE & POORMAN, 1967).

PREVIOUS COLLECTING IN THE VICINITY OF CONSAG ROCK

Historically, the Jesuit, Father Fernando Consag was among the first to make a reconnaissance trip in 1746 to the extreme northern reaches of the Gulf of California (ENGELHARDT, 1929: p. 266). The rock named for him is 289 feet high. A manuscript map by Consag (ADDITION-TON MSS), with notations in his own handwriting, states that at Santa Isabel, "*hasta aqui llegan los placeros de perlas*" (thus far extend the pearl grounds). Santa Isabel was at a point on the east coast of peninsular Lower California about where Puertecitos is today.

Two records of molluscan collecting in the vicinity of Consag Rock appear in the literature: (1) The Allan Hancock Pacific Expeditions of 1937 and 1940 collected on and around Consag Rock and in San Felipe Bay. FRASER (1943) listed 6 dredging stations and 2 shore stations, but the mollusks remain largely unreported. (2) The 1957 Puritan - American Museum of Natural History Expedition reported 2 dredging stations 14 miles SW of Consag Rock. A general account of this expedition was given by EMERSON (1958).

¹ 15012 El Soneto Drive, Whittier, California 90605

² 9536 La Cima Drive, Whittier, California 90603

OCEANOGRAPHIC CONSIDERATIONS

Very little is known concerning meteorological and oceanographic conditions at San Felipe and Consag Rock. Since the Jesuit missionaries established no mission at San Felipe we must rely on other, more recent, reports for information on air and water temperatures. No year around water temperature data are available (RODEN & GROVES 1959: p. 11). The air temperature in the northeastern section of the peninsula shows extremes from 18° F in winter to 128° F in summer (NELSON, 1922: p. 102), making this the hottest and driest part of Lower California. Occasionally violent storms come up the Gulf of California from the south or are driven over the high Peninsular Range from the Pacific ocean. The most recent devastating storm occurred at San Felipe on September 1, 1967. Summer rains are capricious and irregular; one place may be deluged while another close by may not receive a single drop. These rains are commonly in the form of cloudbursts, usually in July, August, or September with resultant heavy runoff into the western edge of the Gulf of California. Winter rains are also irregular and sometimes last only a few hours. Some years no winter rains fall. Average yearly rainfall is about 2.5 inches (Nelson, 1922: pp. 96, 98, 99).

One cannot discuss oceanographic conditions in this area without due consideration of the effects of the Colorado River upon the waters of the Gulf of California. Prior to 1938, when Boulder Dam was completed, the Colorado River watershed annually discharged billions of tons of silt into the waters of the Gulf. Since the tidal current in the Gulf is counterclockwise (BERRY, 1954: p. 24; RODEN, 1958: pp. 24, 33) this detrital material had been carried from the Colorado River as far south as San Felipe Point, an isolated volcanic part of the Peninsular Range on the western shore of the Gulf. As a result of this deluge of silt there are many pockets of mud in the northern end of this body of water. According to SYKES (1937: p. 107), "Driftwood, plainly of Colorado River origin, has been observed as far to the southward as the San Luis Islands, along the Lower California shore (latitude 30° N), and in this case the transporting agency was probably tidal current rather than wind." In the literature no such phenomenon has been reported on the Sonoran coast. With the completion of Boulder Dam and the further construction of an impounding and diversion dam at Parker, the movement of fresh detrital material is practically stopped (SYKES, 1937: p. 175).

San Felipe Bay is a shallow depression on the west side of the Gulf, with a sandy bottom and a tidal range of about 22 feet (7 m). The sea floor outside the bay slopes

very gradually to a depth of 27 fms (48 m) beyond Consag Rock at Lat. 31°12'N, Long. 114°22'W with many mud holes and sandy ridges present. Extensive evaporation, which increases salinity, occurs on the shallow protected bays of San Felipe as well as at Adair Bay on the Sonoran side and Concepción Bay on the Lower California side (RODEN & GROVES, 1959: p. 16). In the 30 years since the completion of Boulder and Parker Dams the silt, being more dense than the current-driven sand, still lies in pockets on the ocean floor. The current U.S. Navy Oceanographic map (Chart 620) shows these deposits.

FAUNAL RELATIONSHIPS

The following lists record 217 species of mollusks, of which 58 are pelecypods, 5 are scaphopods, and 154 are gastropods. One is doubtfully identified ("cf") and 7 are identified only to genus.

Because, to us, there are no known records of mollusks collected this far north in the Gulf of California we consider all specimens collected to represent northern extensions of the known range with the exceptions of *Calliostoma palmeri*, *Crepidula arenata*, *Crepidula incurva*, *Terebra glauca*, *Terebra armillata*, *Nassarius iodes*, and *Nassarius moestus* which the senior author collected intertidally in November 1967 at El Golfo, Sonora, Mexico.

Although the molluscan fauna is predominantly Panamic, some members of the Californian province are represented in the northern Gulf. Specimens of the following species occurring in both the Californian and Panamic provinces are also to be found in trawling at Consag Rock and in the immediate vicinity of San Felipe Bay: *Nucula linki* DALL, *Hiatella arctica* (LINNAEUS), *Aesopus chrysallodes* CARPENTER, and *Iscelia fenestrata* CARPENTER.

The faunal element restricted to the northern and northwestern shores is less well known but includes: *Acmaea strongiana*, *Nomaeopelta dalliana*, *Cantharus macropsira*, *Turritella anactor*, *Terebra berryi*, *Terebra dushanae*, *Recluzia palmeri* and *Melampus mouseleyi*. Specimens of *Nassarina pammicra* reported by McLEAN (1961) from Los Angeles Bay as a range extension northward from Nicaragua have also been collected at Gonzaga Bay by DuSHANE & SPHON (1968) as well as at Puertecitos by DuSHANE (1964). *Terebra berryi* and *Terebra dushanae* seem to have a very limited distribution on the northwestern shores of the Gulf of California (type locality for both: Puertecitos). The former has not been found living at San Felipe but occurs sparingly at Gonzaga Bay to the south. The latter species occurs inter-

tidally uncommonly at Agua Chale, 24 miles south of San Felipe. *Terebra variegata*, well known throughout the Gulf, is missing from the San Felipe fauna, but was trawled off Agua Chale. *Strombina dorsata* occurs at both Puertecitos and Gonzaga Bay but is unrecorded at Los Angeles Bay. It occurs uncommonly at San Felipe Bay. *Nassarina anitae*, described by CAMPBELL (1961) from Guaymas, occurs uncommonly on clumps of *Pteria sterna* in the vicinity of Consag Rock. Specimens collected are essentially the same as the ones PARKER (1963: p. 167) reported from 11 to 26 meters in the northern Gulf.

The more unusual extensions of range northward are represented by specimens including: *Nucula linki*, *Diplothyra curta*, *Ostrea megodon*, *Lophocardium cumingii*, *Psephidia cymata*, *Macoma undulata*, *Aequipecten palmeri*, *Iselica fenestrata*, *Clathrodrillia adonis*, *Crassispira bacchia*, *Clathurella acapulcana*, *Vitulularia salebrosa*, and *Conus tornatus*.

Allyn G. Smith (personal communication) reports that a new species of *Fusinus* was taken in the area of Consag Rock. Another species of *Fusinus* awaits determination after a comparison of the radula with intertidal specimens of *Fusinus ambustus*.

An unusual occurrence of an arthropod taken merits a note: *Eupagurus varians* BENEDICT, together with its commensal hydractinian *Janania mirabilis* STECHOW (Treatise Inv. Paleo.: p. 84) was common at stations 7, 8, and 13.

SYSTEMATIC ACCOUNT

The following format is adopted:

1. The order in the checklist, the nomenclature, and the species numbers are those given by KEEN (1958) with a few changes as new material was discovered. References to species listed by KEEN may be located in her bibliography. References to species described since 1958 are included in the present paper.
2. The habitat and relative abundance of species taken are given. Indications are made for those species not taken alive.
3. The collecting stations referred to in the list by numbers are shown on the accompanying map. All species reported are from depths of from 3 to 21 fms (5 to 38 m).
4. Unusual range extensions are indicated by an asterisk (*) following the "Keen numbers." The area from which the range is extended follows the collector's initial.
5. The following collectors are designated by initials:

Twila Bratcher	B
Ellen Brennan	Br
Don Cadien	C
Billee Dilworth	D
Joseph & Helen DuShane	Du
William & Joyce Gemmell	G
Roy Poorman	P
William E. Viney	V
Erwin & Gertrude Wahrenbrock	W

The specimens reported are in the private collections of the individuals named and the Cadien collection is in the Los Angeles County Museum of Natural History.

ACKNOWLEDGMENTS

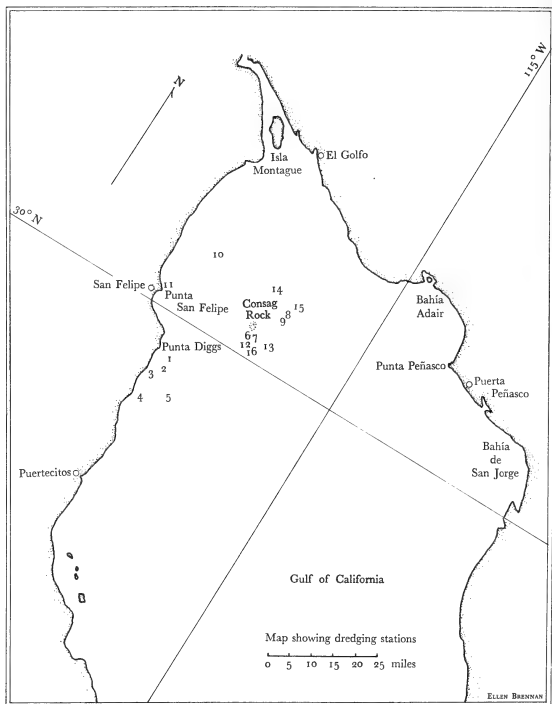
We wish to express our gratitude to Dr. A. Myra Keen and to Roy Poorman for identification of many of the small species; to Dr. James H. McLean of the Los Angeles County Museum of Natural History for critical evaluation of the manuscript; to Don Cadien of the same institution for identification of the nudibranchs.

ECOLOGICAL NOTES ON 16 COLLECTING STATIONS

(see Map)

Over a three-day period mollusks were trawled at the following 16 stations. After an initial pull at 3 mph, which proved to be too rapid, all pulls were made at 2 mph, the minimum speed of the boat. In the notes below, longitude and latitude are given for the beginning of each pull.

1. Two miles off Punta Diggs, 12 miles S of the town of San Felipe; Lat. 30°51'12"N, Long. 114°39'W; course 160°. The nets were down for 40 minutes over sand bottom at a depth of 5 fm. Fish and sea stars comprised the bulk of the material trawled. The stomachs of one species of sea star yielded many mollusks, among them species of *Nuculana*, *Pitar*, *Pandora*, *Olivella* and *Acteocina*.
2. Two miles offshore from Alicia Playa, 18 miles S of the town of San Felipe; Lat. 30°46'N, Long. 114°40'W; course 130°. The nets trawled over sand bottom at a depth of 6 to 7 fm. A great number of sea stars were included in this haul and their stomachs yielded species of *Crassinella*, *Trigoniocardia*, *Nassarius*, and *Olivella*, along with *Chione mariae* and juvenile *Cosmioconcha palmeri*.



3. Four rope tangles were set south of Alicia Playa, 18 miles S of the town of San Felipe, Lat. $30^{\circ}44'30''$ N, Long. $114^{\circ}41'$ W, in 3 fm of water over rocks. They were baited with decaying fish contained in nylon bags. The tangles were left in the water about 3 hours and when retrieved, the bait was gone. Quick examination on the spot revealed no mollusks; however, later careful examination revealed several specimens of *Anachis varia*, *A. milium*, and a juvenile *Muricanthus nigrilus* which had crawled high into the untwisted strands of the tangle. If a way could be devised to keep the bait in the tangles, this could prove to be a good collecting device.
4. Two miles offshore from Agua Chale, 24 miles S of the town of San Felipe; Lat. $30^{\circ}41'$ N, Long. $114^{\circ}40'06''$ W; course 195° . This pull covered one mile of sand bottom at a depth of 5 fm paralleling an offshore rock reef. It yielded fish, crustaceans, and 2 species of sea stars. Examination of the stomachs of these echinoderms produced several species of *Nuculana*, *Pandora brevifrons*, *Calliostoma palmeri*, and *Eupleura muriciformis*.
5. Eight miles E of Agua Chale, 24 miles S of San Felipe; Lat. $30^{\circ}41'$ N, Long. $114^{\circ}32'$ W; course 340° . This one-mile pull over sand and mud pockets at a depth of 10 fm yielded a large quantity of fish and 2 species of sea stars, their stomachs containing species of *Nuculana*, juvenile *Trachycardium senticosum*, *Chione mariae*, *C. gnidia*, and *C. pulicaria*.
6. Two miles SW of Consag Rock, Lat. $31^{\circ}06'$ N, Long. $114^{\circ}30'30''$ W; course 095° . On this pull and all subsequent ones, more weight was added to the nets, producing better results. The nets trawled over one mile of sand bottom at a depth of 12 fm, producing quantities of *Hexaplex erythrostomus*, *Muricanthus nigrilus* with eggs, *Calyptrea*, *Crepidula*, and *Crucibulum* were common attached to dead shells.
7. Two miles S of Consag Rock, Lat. $31^{\circ}05'$ N, Long. $114^{\circ}28'30''$ W; course 100° . On this pull the nets trawled over $\frac{3}{4}$ of a mile of sand bottom at a depth of 11 fm. Among the mollusks trawled were *Calliostoma palmeri*, *Ficus ventricosa*, *Murex elenensis*, *M. recurvirostris lividus*, *Pteropurpura erinaceoides*, *Acanthina tuberculata*, and *Cancellaria cassidiformis*. Basket stars of the genus *Crinoidea* were common as were sponges, red-brown in color, each growing upon and completely enveloping a shell.
8. Eight miles ENE of Consag Rock, Lat. $31^{\circ}08'30''$ N, Long. $114^{\circ}21'$ W; course 340° . A one mile pull over sand bottom at a depth of 18 fm produced many clumps of living *Pteria sterna* among the lamellae of which were *Septifer zetekii*, *Hiatella arctica*, *Epitonium keraium*, *Iselica fenestrata*, and *Nassarina anitae*. *Vitularia salebrosa* was taken living on dead *P. sterna* shells, as was *Modiolus capax*.
9. Seven miles ENE of Consag Rock, Lat. $31^{\circ}08'$ N, Long. $114^{\circ}21'$ W; course 020° . A one mile pull over sand bottom at 15 fm depth produced approximately the same mollusk species as were trawled at Station 8, with the addition of *Lioberus splendida* and *Atrina tuberculosa*.
10. Seventeen miles NW of Consag Rock, Lat. $31^{\circ}20'18''$ N, Long. $114^{\circ}41'$ W. After a one mile pull at a depth of 14 fm over mud bottom, the nets were full of *Astropecten*. Examination of the stomachs of the sea stars produced such mollusks as *Nucula linki*, *Natica broderipiana*, and *Strombina dorsata*.
11. Three-fourths of a mile offshore, beginning north of San Felipe Point and ending south of San Felipe Point; Lat. $31^{\circ}02'30''$ N, Long. $114^{\circ}48'$ W. This pull was $\frac{3}{4}$ of a mile long, over sand and mud bottom at a depth of 6 fm. The nets yielded a coral-related material containing *Diplohyra curta* and *Lithophaga attenuata rogersi*. A large mass of aborted egg strings was found to contain a multitude of small shells. Among the genera represented were *Nucula*, *Nuculana*, *Balcis*, *Niso*, *Epitonium*, *Cyclostremiscus*, *Seila*, *Aesopus*, *Nassarina*, *Anachis*, *Clavus*, *Clathrodrillia*, and *Mangelia*.
12. Three miles SW of Consag Rock, Lat. $31^{\circ}04'30''$ N, Long. $114^{\circ}31'30''$ W; course 080° . This was a one mile pull over sand bottom at a depth of 13 fm. The other trawl brought up *Polinices intemeratus*, *Hexaplex erythrostomus*, *Muricanthus nigrilus* with eggs, and *Solenostrea capitaneus*.
13. Five miles SSE of Consag Rock, Lat. $31^{\circ}02'12''$ N, Long. $114^{\circ}26'24''$ W; course 070° . A one mile pull over sand bottom at 11 fm depth produced such mollusks as *Ficus ventricosa*, *Murex recurvirostris lividus*, *Pteropurpura erinaceoides*, *Cancellaria cassidiformis*, and *Conus poormani*.
14. Eight miles NE of Consag Rock, Lat. $31^{\circ}12'$ N, Long. $114^{\circ}22'$ W; course 080° . A $\frac{3}{4}$ mile pull over sand and clay bottom at a depth of 21 fm produced essentially the same species as were trawled at Stations 8 and 9.
15. Ten miles ENE of Consag Rock, Lat. $31^{\circ}09'12''$ N, Long. $114^{\circ}17'36''$ W; course 314° . This was a one mile pull over sand and clay bottom at 16 fm depth. The trawl was full of clumps of *Pteria sterna* attached to which were *Ostrea conchaphila*, *O. megodon*, *O. pal-*

mula, *Chama sordida*, *C. buddiana*, and *Nassarina pam-mica*.

16. Five miles S of Consag Rock, Lat. 31°03'N, Long. 114°31'30"W; course 270°. This one mile pull over sand bottom at 11 fm depth produced essentially the same mollusk species as were trawled at Station 13.

PELECYPODA

- 1 *Nucula declivis* HINDS, 1843. Uncommon (10, 11), 6 - 14 fm, mud and sand bottom, in sea star stomachs and entangled in aborted egg mass (B, C, D, G, P).
- 3* *Nucula linki* DALL, 1916. Rare (10), 14 fm, mud and sand bottom, from sea star stomachs; Pt. Fermin, Gulf of California (Du, G).
- 10 *Nuculana elenensis* (SOWERBY, 1833). Uncommon (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (Br, C, Du).
- 12 *Nuculana impar* (PILSBRY & LOWE, 1932). Common (1, 4, 5, 10, 15), 5 - 16 fm; sand, mud, and clay bottom; in sea star stomachs (B, Br, C, D, G).
- 13 *Nuculana laevis* (PILSBRY & LOWE, 1932). Common (4, 5, 9, 10, 14), 5 - 21 fm; sand, mud, and clay bottom; in sea star stomachs (B, C, D, Du, G, P).
- 87 *Septifer zeteki* HERTLEIN & STRONG, 1946. Rare (8), 18 fm, sand bottom (C, Du).
- 91a *Lithophaga attenuata rogersi* BERRY, 1957. Uncommon (11), 6 fm, in chunks of coral-related material (C, W).
- 101 *Modiolus capax* (CONRAD, 1837). Rare (8), 18 fm, attached to *Pteria sterna* (Du).
- 106 *Lioberus splendida* DUNKER, 1857. Uncommon (7, 14), 11 - 21 fm, sand bottom and on *Pteria sterna* (Br, Du, G).
- 107 *Pteria sterna* (GOULD, 1851). Common (8, 9, 14, 15), 15 - 21 fm, sand and clay bottom (B, Br, C, D, Du, G, P, V, W).
- 113 *Atrina tuberculosa* (SOWERBY, 1835). Rare (9), 15 fm, sand bottom (C).
- 119 *Ostrea conchaphila* CARPENTER, 1857. Uncommon (9, 10, 14, 15), 15 - 21 fm, sand and clay bottom, on dead *Pteria sterna* shells (Du).
- 123 *Ostrea megodon* HANLEY, 1846. Rare (15), 16 fm, sand and clay bottom (D).
- 124 *Ostrea palmula* CARPENTER, 1857. Uncommon (9, 10, 14, 15), 15 - 21 fm, sand and clay bottom, on *Pteria sterna* (Du).
- 126 *Pecten vogdesi* ARNOLD, 1906. Uncommon as valves and dead specimens (8, 13), 11 - 18 fm, sand bottom (Br).
- 128 *Aequipecten palmeri* (DALL, 1897). Common (7, 8, 9, 13, 16), 11 - 18 fm, sand bottom (Br, C, Du, G, P).
- 132 *Aequipecten circularis* (SOWERBY, 1835). Common (6, 7, 8, 9, 12, 13, 14, 15, 16), 11 - 21 fm, sand and clay bottom; attached to *Pteria sterna*, gastropods, and in sea star stomachs (Br, C, Du, G, P).
- 147 *Plicatula anomioidea* KEEN, 1958. Uncommon (15), 16 fm, sand and clay bottom, on dead *Pteria sterna* shells (Du).
- 159 *Crassinella pacifica* (C. B. ADAMS, 1852). Uncommon (2, 11), 6 fm, sand and mud bottom, in sea star stomachs and entangled in aborted egg mass (B, Br, C, D, Du, P).
- 231 *Myrella compressa* (DALL, 1913). Rare (9), 15 fm, sand bottom, in sea star stomachs (P).
- 238 *Chama buddiana* C. B. ADAMS, 1852. Uncommon (8), 18 fm, sand bottom, juveniles attached to dead shells (C, Du).
- 241 *Chama sordida* BRODERIP, 1835. Common (8, 9, 14, 15), 10 - 11 fm, sand and clay bottom, attached to *Pteria sterna* (Br, C, Du, G).
- 251 *Trachycardium senticosum* (SOWERBY, 1833). Common (5, 16), 10 - 11 fm, sand bottom, juveniles in sea star stomachs (Br, C, Du, P).
- 256 *Trigoniocardia granifera* (BRODERIP & SOWERBY, 1829). Uncommon (2, 4), 5 - 7 fm, sand bottom, juveniles in sea star stomachs (C, Du, G, P).
- 262 *Laevicardium elatum* (SOWERBY, 1833). Rare (6), juvenile, 12 fm, sand bottom (C).
- 263 *Laevicardium elenense* (SOWERBY, 1840 [?1841]). Uncommon (11, 12), 6 - 13 fm, sand and mud bottom, juveniles in crevices of coral-related material and in sea star stomachs (Br, C, G, P).
- 264 *Lophocardium annettae* (DALL, 1889). Rare (14), valve only, 21 fm, sand and clay bottom (Br).
- 265 *Lophocardium cumingii* (BRODERIP, 1833). Rare (9), valve only, 15 fm, sand bottom (Du).
- 282 *Transennella tantilla* (GOULD, 1853). Rare (9), 15 fm, sand bottom, in sea star stomachs (P).
- 286 *Pitar helenae* OLSSON, 1961. Uncommon (6, 10), 12 - 14 fm, sand and mud bottom, in sea star stomachs (Br, Du).
- 287 *Pitar perfragilis* PILSBRY & LOWE, 1932. Rare (4), 5 fm, sand bottom, in sea star stomachs (P).
- 296 *Pitar concinnus* (SOWERBY, 1835). Common (1, 2, 4, 5), 5 - 10 fm, sand and mud bottom, in sea star stomachs (C, Du, G, P).
- 306 *Dosinia ponderosa* (GRAY, 1838). Uncommon (2, 13), 6 - 11 fm, sand bottom, juveniles in sea star stomachs (C, Du, P).

- 315 *Psephidia cymata* DALL, 1913. Uncommon (10, 14, 15), 14-21 fm, sand and clay bottom, in sea star stomachs (C, Du, P).
- 326 *Chione gnidia* (BRODERIP & SOWERBY, 1829). Common, juveniles (1, 2, 4, 5), 5-10 fm, sand and mud bottom, in sea star stomachs (C, Du, G, P).
- 327 *Chione pulicaria* (BRODERIP, 1835). Uncommon (2, 3, 5), 5-10 fm, sand and mud bottom, juveniles in sea star stomachs (Br, C, Du, P).
- 331 *Chione mariae* (D'ORBIGNY, 1845). Common (2, 4, 5, 10, 13, 16), 5-14 fm, sand and mud bottom, in sea star stomachs (Br, C, Du, G, P).
- 335 *Chione picta* WILLETT, 1944. Rare (2), 6-7 fm, sand bottom, in sea star stomachs (B).
- 392 *Tellina amianta* DALL, 1900. Common (10, 14, 15), 14-21 fm, mud, sand, and clay bottom; from washings of *Pteria sterna* and in sea star stomachs (Br, C, Du, P).
- 425 *Macoma undatella* (HANLEY, 1844). Uncommon (10), 14 fm, mud bottom, in sea star stomachs (Br, Du, G, P).
- 436 *Macoma pacis* PILSBRY & LOWE, 1932. Uncommon (4), 5 fm, sand bottom, in sea star stomachs (G).
- 438 *Strigilla cicerula* (PHILIPPI, 1846). Rare (9), 15 fm, sand bottom, in sea star stomachs (G).
- 441 *Strigilla lenticula* PHILIPPI, 1846. Rare (7), 11 fm, sand bottom, in sea star stomach (P).
- 450 *Donax gracilis* HANLEY, 1845. Uncommon (4, 5), 5-10 fm, sand and mud bottom, in sea star stomachs (Br, Du, G).
- 475 *Tagelus politus* (CARPENTER, 1857). Uncommon (11), 6 fm, sand and mud bottom, juveniles entangled in aborted egg mass (C, P).
- 483 *Semele guaymasensis* (PILSBRY & LOWE, 1932). Uncommon (6), 12 fm, sand bottom, in sea star stomachs (Du, G, P).
- 489 *Semele pacifica* DALL, 1915. Uncommon (7), 11 fm, sand bottom, in sea star stomachs (Du, G).
- 507 *Abra tepocana* DALL, 1915. Rare (5), 10 fm, sand and mud bottom, in sea star stomachs (G).
- 527 *Corbula nasuta* SOWERBY, 1833. Common (6 to 10, 12 to 16), 11-21 fm, sand, mud, and clay bottom; in sea star stomachs and in washings from *Pteria sterna* (B, Br, C, D, Du, G, P).
- 539 *Gastrochaena ovata* SOWERBY, 1834. Rare, valves only (11), 6 fm, sand and mud bottom, embedded in coral-related material (Br).
- 542 *Hiatella arctica* (LINNAEUS, 1767). Common (7, 8, 9, 13, 14, 15), 11-21 fm, sand and clay bottom, nestling on outer edges of *Pteria sterna* and on *Murchantus nigrinus* (Br, C, Du, G, P).
- 545 *Panope globosa* DALL, 1898. Valve only (13), 11 fm, sand bottom (C).
- 553 *Diplothyra curta* (SOWERBY, 1834). Common (11), 6 fm, sand and mud bottom, boring in coral-related material (Br, C, W).
- 567 *Pandora brevifrons* SOWERBY, 1835. Common (4, 6, 7, 12, 13, 16), 5-13 fm, sand bottom, in sea star stomachs (Br, C, G).
- 569 *Pandora claviculata* CARPENTER, 1855. Uncommon (10), 14 fm, mud bottom, in sea star stomachs (Du).
- 576 *Pandora granulata* DALL, 1915. Uncommon (1, 2), 5-7 fm, sand bottom, in sea star stomachs (Du, P).
- 591* *Asthenothaerus villosior* CARPENTER, 1864. Uncommon (10), 14 fm, mud bottom, in sea star stomachs; Cape San Lucas, Lower California (P).
- 597 *Cuspidaria didyma* (HINDS, 1843). Rare (14), valves only, 21 fm, sand and clay bottom, from sea star stomachs (Du).

SCAPHOPODA

- 2 *Dentalium inversum* DESHAYES, 1826. Uncommon (14), 21 fm, sand and clay bottom, in sea star stomachs (B, D).
- 3 *Dentalium oerstedii* MÖRCH, 1860. Common (9, 11, 15), 6-10 fm, sand, clay, and mud bottom; in sea star stomachs and entangled in aborted egg mass (B, Br, C, D, Du, P).
- 5 *Dentalium sectum* DESHAYES, 1826. Uncommon (4), 5 fm, sand bottom, in sea star stomachs (G).
- 9 *Dentalium quadrangulare* SOWERBY, 1832. Uncommon (8), 18 fm, sand bottom, in sea star stomach (G).
- 12 *Cadulus panamensis* PILSBRY & SHARP, 1897. Common (1, 2, 8, 10, 11), 5-18 fm, sand and mud bottom, entangled in aborted egg mass, in sea star stomachs, and in washings from *Pteria sterna* (B, Br, C, D, Du, G, P).

GASTROPODA

- 30 *Diodora alta* (C. B. ADAMS, 1852). Rare (8), 18 fm, sand bottom, attached to dead shell (C).
- 45 *Calliostoma marshalli* LOWE, 1935. Common (2, 4, 8, 9, 14, 15), 18 fm, sand and clay bottom, in sea star stomachs and in clumps of *Pteria sterna* (B, C, D, Du, G).
- 47 *Calliostoma palmeri* DALL, 1871. Uncommon (7, 8, 13), 11-18 fm, sand bottom, also in sea star stomachs (Br, C, Du, P).

- 60 *Solariella triplostephanus* DALL, 1910. Rare (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (G).
- 66 *Turbo mazatlanicus* PILSBRY & LOWE, 1932. Rare (4), 5 fm, sand bottom, in sea star stomachs (B, D). *Liotia balboa* STRONG & HERTLEIN, 1939. Rare (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (B, D, G). *Liotia stearnsi* DALL, 1918. Rare (2), 6-7 fm, sand bottom, in sea star stomachs (B, D). *Arene rammata* (DALL, 1918). Uncommon (4, 5), 5-10 fm, sand and mud bottom, in sea star stomachs (B, D). *Tricolia equilirata* CARPENTER, 1857. Uncommon (9), 15 fm, sand bottom, in sea star stomachs (B, D). *Balcis mexicana* BARTSCH, 1917. Rare (1, 11), 5-6 fm, sand and mud bottom, in sea star stomachs and entangled in aborted egg mass (Br, C, Du).
- 87 *Niso excolpa* BARTSCH, 1917. Uncommon (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (B, C, D, Du). *Epitonium keratum* DALL, 1919. Uncommon (8, 11), living on *Pteria sterna* shells, 18 fm; entangled in aborted egg mass, 6 fm, sand and mud bottom (Br, C, Du).
- 99 *Epitonium walkerianum* HERTLEIN & STRONG, 1951. Uncommon (2, 11), 5-6 fm, sand and mud bottom, in sea star stomachs and dead in aborted egg mass (Br, C, G).
- 105 *Epitonium reflexum* (CARPENTER, 1856). Uncommon (11), 6 fm, sand and mud bottom, dead in aborted egg mass (C, Du).
- 106 *Epitonium bakanstranum* KEEN, 1962. Uncommon (11), 6 fm, sand and mud bottom, dead in aborted egg mass (Br, C, Du).
- 107 *Epitonium appressicostatum* DALL, 1917. Uncommon (11), 6 fm, sand and mud bottom, dead in aborted egg mass (Du).
- 108 *Epitonium barbarinum* DALL, 1919. Common (11), 6 fm, sand and mud bottom, dead in aborted egg mass (B, D, P).
- 118 *Epitonium durhamianum* HERTLEIN & STRONG, 1951. Rare (11), 6 fm, sand and mud bottom, dead in aborted egg mass (B, D, P).
- * *Lacuna succinea* MÖRCH, 1860. Rare (8), 18 fm, sand bottom, juveniles in washings from *Pteria sterna*; Gulf of Nicoya, Costa Rica (C, Du). *Cyclostremiscus bifrontia* CARPENTER, 1857. Rare (4), 5 fm, sand bottom, in sea star stomach (G). *Cyclostremiscus tricarinatus* C. B. ADAMS, 1852. Common (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (B, Br, C, D, Du, P).
- Macromphalina* sp. Rare (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (Br).
- Delphinoidea hambachi* STRONG & HERTLEIN, 1939. Rare (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (P).
- Teinostoma amplexans* CARPENTER, 1857. Rare (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (C).
- * *Teinostoma ecuadorianum* PILSBRY & OLSSON, 1941. Rare (11), 6 fm, sand and mud bottom, in aborted egg mass; Punta Blanca, Ecuador (B, D, P). *Vitrinella dalli* (BARTSCH, 1911). Uncommon (7), 11 fm, sand bottom, in sea star stomach (D). *Assiminea* sp. Uncommon (15), 16 fm, sand and clay bottom, on *Pteria sterna* shells (G).
- 180 *Turritella anactor* BERRY, 1957. Uncommon (7, 13), 11 fm, sand bottom, dead specimens and juveniles in sea star stomachs (Br, C, Du, G).
- 187 *Turritella nodulosa* KING & BRODERIP, 1832. Uncommon (11), 6 fm, sand and mud bottom, juveniles entangled in egg mass (P). *Metaxia* sp. Uncommon (11), 6 fm, sand and mud bottom, in aborted egg mass (G). *Seila assimolata* C. B. ADAMS, 1852. Common (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (B, Br, D, P). *Seila* sp. Uncommon (11), 6 fm, sand and mud bottom, entangled in aborted egg mass (C, Du).
- Triphora hannai* BAKER, 1926. Rare (8), 18 fm, sand bottom, in washings from *Pteria sterna* (Du).
- * *Iselica fenestrata* CARPENTER, 1864. Common (8, 9, 14, 15), sand and clay bottom, on *Pteria sterna*; San Diego, California (Br, C, Du, G, P).
- 233 *Calyptrea mamillaris* BRODERIP, 1834. Common (1, 7, 8, 9, 12 to 16), 5-21 fm, sand, clay, and mud bottom; attached to dead shells (Br, Du, P).
- 240 *Crepidula arenata* (BRODERIP, 1834). Common (7, 8, 13), 11-18 fm, sand bottom, on *Calliostoma palmeri* (Du).
- 242 *Crepidula incurva* (BRODERIP, 1834). Common (7, 8, 13), 11-18 fm, sand bottom, on *Calliostoma palmeri* (Du).
- 245 *Crepidula onyx* SOWERBY, 1824. Common on dead shells (6, 7, 12, 13), 11-13 fm, sand bottom (B, Br, D, Du, P).
- 248 *Crepidula striolata* MENKE, 1851. Uncommon (7, 11), 6-11 fm, sand and mud bottom, entangled in aborted egg mass and on dead bivalves (G, P).
- 251 *Crucibulum personatum* KEEN, 1958. Common (11, 13, 16), sand and mud bottom, on coral-related material and on dead shells (B, Br, C, D, Du, P).

- 252 *Crucibulum scutellatum* (WOOD, 1828). Common (13, 16), 11 fm, sand bottom, on other shells (Br, C, Du, P).
- 254 *Crucibulum spinosum* (SOWERBY, 1824). Common (8, 11, 14, 15), 6 - 21 fm, sand, mud, and clay bottom; juveniles on other shells and entangled in aborted egg mass (Du, G, P).
- 261 *Natica idiopoma* PILSBRY & LOWE, 1932. Rare (8), 18 fm, sand bottom, in sea star stomachs (B, P).
- 263 *Natica broderipiana* RÉCLUZ, 1844. Uncommon. (10), 14 fm, mud bottom, in sea star stomachs (Br, G).
- 266 *Polinices bifasciatus* (GRIFFITH & PIGEON, 1834 from GRAY MS.). Uncommon (13), 11 fm, sand bottom, juvenile in sea star stomach (Br).
- 269 *Polinices intemeratus* (PHILIPPI, 1853). Uncommon (12), 13 fm, sand bottom (Du).
- 272 *Polinices uber* (VALENCIENNES, 1832). Uncommon (1, 2, 4), 5 - 7 fm, sand and mud bottom, in sea star stomachs (B, D, G).
- 274 *Polinices reclusianus* (DESHAYES, 1839). Common (1, 4, 5), 5 - 10 fm, juveniles in sea star stomachs (B, Br, C, D, Du, G, P).
- 280 *Lamellaria inflata* (C. B. ADAMS, 1852). Rare (14), 21 fm, sand and clay bottom, in washings from *Pteria sterna* (B).
- 289 *Erato columbella* MENKE, 1847. Uncommon (15), 16 fm, sand and clay bottom with clumps of *Pteria sterna*, in sea star stomachs (D, P).
- 317 *Ficus ventricosa* (SOWERBY, 1825). Uncommon (7, 13, 14), 11 - 21 fm, sand and clay bottom (C, D, Du, G).
- 335 *Murex elenensis* DALL, 1909. Uncommon (7, 16), 11 fm, sand bottom (Du, V).
- 336a *Murex recurvirostris lividus* CARPENTER, 1857. Uncommon (7, 13), 11 fm, sand bottom (B, C, D, P).
- 339 *Hexaplex erythrostomus* (SWANSON, 1831). Common (6, 7, 8, 12, 13, 14), 11 - 21 fm, sand and clay bottom (Br, C, Du, P, V, W).
- 344 *Muricanthus nigratus* (PHILIPPI, 1845). Common (6, 7, 12, 13), 11 - 13 fm, sand bottom (B, Br, C, D, Du, G, P, V).
- 348 *Pteropurpura erinaceoides* (VALENCIENNES, 1832). Uncommon (7, 13), 11 fm, sand bottom (B, Br, D, V).
- 364 *Eupleura muriciformis* (BRODERIP, 1833). Common (4, 11), 5 - 6 fm, sand and mud bottom, juveniles in sea star stomachs and entangled in aborted egg mass (B, Br, C, D, Du, G, P).
- 370* *Vitularia salebrosa* (KING & BRODERIP, 1832). Uncommon (8, 9, 14, 15), sand and clay bottom, attached to *Pteria sterna*; Guaymas, Sonora, Mexico (Br, C, Du, G).
- 409 *Acanthina tuberculata* (SOWERBY, 1835). Uncommon (7), 11 fm, sand bottom (C, Du).
- 417 *Aesopus sanctus* DALL, 1919. Uncommon (11), 6 fm, sand and mud bottom, in aborted egg mass (B, Br, D, P).
- * *Aesopus chrysallodes* CARPENTER, 1864. Rare (11), 6 fm, sand and mud bottom; San Diego, California (Du, G).
- 429 *Anachis diminuta* (C. B. ADAMS, 1852). Uncommon (11), 6 fm, sand and mud bottom, dead in aborted egg mass (Du, P).
- 442 *Anachis milium* (DALL, 1916). Common (3, 11), taken in rope tangles, 3 fm, rocky bottom; in aborted egg mass, 6 fm, sand and mud bottom (Br, C, Du).
- 444 *Anachis nigricans* (SOWERBY, 1844). Uncommon (11), 6 fm, sand and mud bottom, dead in egg mass (P).
- 454 *Anachis sanfelipensis* LOWE, 1935. Uncommon (11), 6 fm, sand and mud bottom, juveniles dead in egg mass (Du).
- 464 *Anachis varia* (SOWERBY, 1832). Common (3, 7, 11), taken in rope tangle, 3 fm, rocky bottom; in sea star stomachs and on chunks of coral-related material, 6 - 11 fm, sand and mud bottom (B, Br, C, D, Du, G, P).
- 470 *Cosmioconcha palmeri* (DALL, 1913). Common as juveniles (2, 5, 8, 11), 6 - 18 fm, sand and mud bottom, in sea star stomachs and in egg mass (B, Br, C, D, Du, G, P).
- 490 *Nassarina pammicra* PILSBRY & LOWE, 1932. Rare (15), 16 fm, sand and clay bottom, on *Pteria sterna* (Du).
- Nassarina anitae* CAMPBELL, 1961. Uncommon (8), 18 fm, sand bottom, in washings from *Pteria sterna* (C, Du, P).
- Nassarina*, possibly new spec. Rare (11), 6 fm, sand and mud bottom, in aborted egg mass (Br, G).
- 508 *Strombina dorsata* (SOWERBY, 1832). Uncommon (10, 11, 14), 6 - 21 fm, sand, mud, and clay bottom; in sea star stomachs and dead in egg mass (Br, Du).
- 512 *Strombina gibberula* (SOWERBY, 1832). Uncommon (14), 21 fm, sand and clay bottom with clumps of *Pteria sterna*, in sea star stomachs (B, C, D, Du, G).
- 541 *Solenosteira capitaneus* (BERRY, 1957). Uncommon (8, 11), 6 - 13 fm, sand bottom (Br, P).
- 543 *Solenosteira macrospira* (BERRY, 1957). Uncommon (8, 11), 6 - 18 fm, sand bottom, dead specimens and juveniles entangled in egg mass (C, Du, G).
- 563 *Phos gaudens* HINDS, 1844. Common (11, 14), 6 to 21 fm, mud, sand, and clay bottom; in sea star stomachs and entangled in egg mass (B, Br, C, D, Du, G, P).

- 577 *Nassarius guaymasensis* (PILSBRY & LOWE, 1932). Common (11), sand and mud bottom, dead in egg mass (C, Du, G).
- 583 *Nassarius pagodus* (REEVE, 1844). Uncommon (2, 6, 10), 6 - 14 fm, sand and mud bottom (Br, Du, P).
- 586 *Nassarius taeniolatus* (PHILIPPI, 1845). Common (2, 10, 11), 6 - 14 fm, sand and mud bottom, in sea star stomachs and entangled in egg mass (B, Br, C, D, Du, G, P).
- 587 *Nassarius versicolor* (C. B. ADAMS, 1852). Common (9, 10, 11), 6 - 15 fm, sand and mud bottom, in sea star stomachs and in egg mass (B, Br, C, D, Du, G, P).
- 591 *Nassarius iodes* (DALL, 1917). Common (11), 6 fm, sand and mud bottom, entangled in egg mass (Du, G, P).
- 593 *Nassarius moestus* (HINDS, 1844). Uncommon (1, 2), 5 - 7 fm, sand bottom, in sea star stomachs (Du, P). *Nassarius howardae* CHACE, 1958. Uncommon (11), 6 fm, sand and mud bottom, entangled in egg mass (Br, P).
- 610 *Fusinus dupetitthoursi* (KIENER, 1846). Uncommon (8), 18 fm, sand bottom, dead (Br, C).
- 612 *Fusinus ambustus* (GOULD, 1853). Uncommon (13), 11 fm, sand bottom, dead (G).
- 614 *Fusinus fredbakeri* LOWE, 1935. One dead specimen (11), 6 fm, sand bottom, entangled in egg mass (C). *Fusinus*, new spec. Uncommon (7, 13), 11 fm, sand bottom (C, Du).
- Fusinus* spec. (possibly new, or dredged form of *F. ambustus*). Common (7 to 10, 13, 16), 11 - 16 fm, sand and mud bottom (B, Br, D, Du, P, V).
- 625 *Olivia spicata* (RÖDING, 1798). Uncommon (11, 14), 6 - 21 fm, sand bottom (Br, C, Du, G).
- 627 *Olivia undatella* LAMARCK, 1810. Uncommon (11), 6 fm, sand bottom, dead (C, Du, P).
- 634a *Olivella fletcheri* BERRY, 1958. Common (2, 4, 7, 11, 13, 16), 5 - 11 fm, sand bottom, in sea star stomachs and in egg mass (Br, C, Du, G, P). *Olivella steveni* BURCH & CAMPBELL, 1963. Rare (4), 5 fm, sand bottom, in sea star stomachs (P).
- 693 *Cancellaria cassidiformis* SOWERBY, 1832. Uncommon (6, 7), 11 - 12 fm, sand and mud bottom (C, Du, G).
- 717 *Daphnella bartschi* DALL, 1919. Rare (13), 11 fm, sand bottom, in sea star stomachs (B, D).
- 741 *Clavus roseolus* (HERTLEIN & STRONG, 1955). Rare (7), 11 fm, sand bottom, in sponge (P).
- 747 *Clavus aeolius* (DALL, 1919). Uncommon (1, 11), 5 - 6 fm, sand and mud bottom, in sea star stomachs and in egg mass (B, C, D, Du, G).
- 748 *Clavus alope* (DALL, 1919). Rare (11), 6 fm, sand and mud bottom, in egg mass (Br).
- 753 *Clavus ianthe* (DALL, 1919). Common (11), 6 fm, sand and mud bottom, in egg mass (B, Br, C, D, Du, G).
- 758 *Clavus pembertoni* LOWE, 1935. Uncommon (7), 11 fm, sand bottom, in sponge (P).
- 765 *Clathrodrillia callianira* DALL, 1919. Rare (15), 16 fm, sand and clay bottom with clumps of *Pteria sterna*, in sea star stomachs (Br).
- 767 *Clathrodrillia maura* (SOWERBY, 1834). Rare (8), 18 fm, sand bottom, in sponge (Br).
- 769 *Clathrodrillia pilsbryi* LOWE, 1935. Uncommon (11, 14), 6 - 21 fm, sand, mud, and clay bottom; in sea star stomachs and in egg mass (B, Br, D, Du, G).
- 771 *Clathrodrillia adonis* (PILSBRY & LOWE, 1932). Uncommon (15), 16 fm, sand and clay bottom, from sea star stomachs (Du).
- 772 *Clathrodrillia alceste* DALL, 1919. Rare (15), 16 fm, sand and clay bottom, in sea star stomach (P).
- 774 *Clathrodrillia duplicata* (SOWERBY, 1834). Uncommon (7), 11 fm, sand bottom, in sponge (B, Br, D).
- 776 *Clathrodrillia halis* DALL, 1919. Uncommon (11), 6 fm, sand and mud bottom, entangled in egg mass (B, D, P).
- 776a *Clathrodrillia halis soror* (PILSBRY & LOWE, 1932). Common (6, 7, 11, 13), 6 - 12 fm, sand and mud bottom; in sponge, in sea star stomachs, and in aborted egg mass (Br, C, Du, G, P).
- 790 *Crassispira bacchia* DALL, 1919. Common (6, 11), 6 - 12 fm, sand and mud bottom, in sea star stomachs and dead in egg mass (B, Br, C, D, Du, P).
- Crassispira* cf. *C. pauxillus* REEVE, 1843. Uncommon (1), 5 fm, sand bottom, in sea star stomachs (Du).
- 825 *Crassispira pluto* PILSBRY & LOWE, 1932. Uncommon (11), 6 fm, sand and mud bottom, dead in egg mass (Br).
- 843 *Hindsiclavella militaris* (REEVE, 1843 ex HINDS MS). Uncommon (7), 11 fm, sand bottom, in sponge (Br).
- 858 *Mangelia aethra* (DALL, 1919). Rare (11), 6 fm, sand and mud bottom, in egg mass (D).
- 862 *Mangelia melita* (DALL, 1919). Common (11), 6 fm, sand and mud bottom, in egg mass (B, Br, C, D, Du, P).
- 866 *Mangelia subdiaphana* CARPENTER, 1864. Rare (11), 6 fm, sand and mud bottom, in aborted egg mass (C, Du).
- 867 *Mangelia antiochroa* PILSBRY & LOWE, 1932. Common in sea star stomachs (B, D, G).
- 868 *Mangelia antipyrgus* PILSBRY & LOWE, 1932. Common (11), 6 fm, sand and mud bottom, in egg mass (C, Du, P).

- 869 *Mangelia cymatias* PILSBRY & LOWE, 1932. Uncommon (9, 11), 6 - 15 fm, sand and mud bottom, in sea star stomachs and in egg mass (B, Br, D).
Mangelia roperi DALL, 1919. Uncommon (1, 11), 5 - 6 fm, sand and mud bottom, in sea star stomachs and entangled in egg mass (B, C, D, Du).
- 875 *Clathurella rigida* (HINDS, 1843). Rare (2), 6 - 7 fm, sand bottom, in sea star stomach (B).
Clathurella trichoides (DALL, 1919). Rare (15), 16 fm, sand and clay bottom (B).
- 881 *Clathurella acapulcana* (PILSBRY & LOWE, 1932). Uncommon (10), 14 fm, mud bottom, in sea star stomachs (Du, G, P).
- 883 *Clathurella adria* (DALL, 1919). Uncommon (11), 6 fm, sand and mud bottom, in aborted egg mass (B, D, Du, P).
- 909 *Pleuroliria artia* BERRY, 1957. Uncommon (8), 18 fm, sand bottom, dead (G).
- 910 *Pleuroliria nobilis* (HINDS, 1843). Rare (13, 15), 11 - 16 fm, sand and clay bottom, in sponges and in *Pteria sterna* clumps (Du, G).
- 911a *Pleuroliria oxytropis albicarinata* (SOWERBY, 1870). Uncommon (7, 13), 11 fm, sand bottom, in sponges (Br, P).
- 913 *Pleuroliria picta* (REEVE, 1843, ex BECK MS). Uncommon (13), 11 fm, sand bottom, in sponges (Du, P).
- 926 *Conus perplexus* SOWERBY, 1857. Rare (8), 18 fm, sand bottom, juveniles (C).
- 928 *Conus tornatus* SOWERBY, 1833, ex BRODERIP MS. Uncommon (9), 11 fm, sand bottom (Du).
Conus poormani BERRY, 1968. Rare (13), 11 fm, sand bottom (Br).
- 956 *Terebra armillata* HINDS, 1844. Juveniles common (11, 14), 6 - 21 fm, sand, mud, and clay bottom; in sea star stomachs and in aborted egg mass (B, Br, C, D, Du).
- 963 *Terebra glauca* HINDS, 1844. Common (6, 11), 6 - 12 fm, sand and mud bottom, juveniles in sea star stomachs and in egg mass (B, Br, C, D, Du, G).
- 966 *Terebra ira* PILSBRY & LOWE, 1932. Uncommon (11), 6 fm, sand and mud bottom, juveniles in aborted egg mass (B, Br, C, D, Du).
- 980 *Terebra variegata* GRAY, 1834. Uncommon (4, 5), 5 - 10 fm, sand and mud bottom, juveniles in sea star stomachs (G).
Terebra dushanae CAMPBELL, 1964. Rare (11), 6 fm, sand and mud bottom, dead in aborted egg mass (G).
- 992 *Acteocina angustior* BAKER & HANNA, 1927. Common (2, 4, 8, 9, 14, 15), 5 - 18 fm, sand and clay bottom, in sea star stomachs and in washings from *Pteria sterna* (B, Br, C, D, Du).
- 994 *Acteocina inculta* (GOULD & CARPENTER, 1857). Uncommon (11), 6 fm, sand and mud bottom, in aborted egg mass (G).
Cylichna defuncta BAKER & HANNA, 1927. Uncommon (1), 5 fm, sand bottom, in sea star stomachs (C, Du).
- 997 *Cylichna fantasma* (BAKER & HANNA, 1927). Rare (11), 6 fm, sand and mud bottom, in aborted egg mass (C, Du).
Cylichna sp. Rare (11), 6 fm, sand and mud bottom, in aborted egg mass (G).
- 1000 *Pyramidella adamsi* CARPENTER, 1864. Rare, in sea star stomachs (G).
- 1003 *Pyramidella mazatlanica* DALL & BARTSCH, 1909. Uncommon (10), mud bottom, in sea star stomachs (D).
Odostomia clathratula C. B. ADAMS, 1852. Rare (11), 6 fm, sand and mud bottom, in egg mass (P).
- * *Odostomia corintoensis* HERTLEIN & STRONG, 1951. Uncommon (6), sand bottom, in sea star stomach; Corinto, Nicaragua (Du).
- * *Turbonilla academica* STRONG & HERTLEIN, 1939. Rare (11), 6 fm, sand and mud bottom, in egg mass; Bahía Honda, Panama (G).
Turbonilla amortajadensis BAKER, HANNA & STRONG, 1928. Rare (11), 6 fm, sand and mud bottom, in egg mass (Du).
Turbonilla azteca BAKER, HANNA & STRONG, 1928. Uncommon (11), 6 fm, sand and mud bottom, in egg mass (Du).
Turbonilla contrerasiana HERTLEIN & STRONG, 1951. Rare (11), 6 fm, sand and mud bottom, in egg mass (Du).
Turbonilla gonzagensis BAKER, HANNA & STRONG, 1928. Rare (11), 6 fm, sand and mud bottom, in egg mass (Du).
Turbonilla prolongata CARPENTER, 1857. Uncommon (10, 11), 6 - 14 fm, mud and sand bottom, in sea star stomachs and in aborted egg mass (B, C, D, P).
Nembrotha eliora MARCUS, 1967. Uncommon (14), 21 fm, sand and clay bottom with clumps of *Pteria sterna* (C).
Coryphella cynara MARCUS, 1967. Uncommon (14), 21 fm, sand and clay bottom with clumps of *Pteria sterna* (C).
Flabellinopsis iodinea (COOPER, 1862). Uncommon (8, 9, 14, 15), 15 - 21 fm, sand and clay bottom with clumps of *Pteria sterna* (C).
Spurilla chromosoma COCKERELL & ELIOT, 1905. Uncommon (8, 9, 14, 15), sand and clay bottom, on *Pteria sterna* (C).

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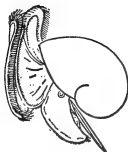
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Two New Species of the Genus *Volva* RÖDING, 1798 (Ovulidae FLEMING, 1828)

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 56)

THE PURPOSE OF THIS PAPER is to describe two new species belonging to the genus *Volva* RÖDING, 1798; it will list and illustrate the more common Pacific species for comparative purposes, and will present the currently accepted synonymy. For further comprehensive detail of the family Ovulidae FLEMING, 1828, the reader is referred to SCHILDER, 1932.

CYPRÆACEA GRAY, 1824

OVULIDAE FLEMING, 1828

Syn.: AMPHIPERATIDAE SCHILDER, 1927 (cm.)

Ovulinac FLEMING, 1828

(Ovulini) FLEMING, 1828

Volva RÖDING, 1798

Mus. Bolten. 21

Type species: *Bulla volva* LINNAEUS, 1758Syn.: *Radius* MONTFORT, 1810.

Conchyl. Syst., 2: 627

Type species: *Bulla volva* LINNAEUS, 1758*Birostra* SWAINSON, 1840.

Treat. Malacol. 1840: 325

Type species: *Bulla volva* LINNAEUS, 1758*(Phenacovolva)* IREDALE, 1930.

Mem. Queensld. Mus., 10 (1): 85

Type species: *Phenacovolva nectarena* IREDALE, 1930

1. *Volva (Phenacovolva) birostris* (LINNAEUS, 1758)

Syst. Nat., ed. 10: 725

(Plate 56, Figure 3)

Syn.: *Ovula longirostrata* SOVERBY, 1828

Zool. Journ. 1828, 4: 160

The species is known to range into Japanese waters and throughout the Malayan Archipelago, from the Gulf of Tonkin, to Vietnam, to Siasi Island, to New Guinea, and along the east coast of Australia. The species appears to maintain a rather constant shell morphology, differing only as to length, and it can be recognized without much difficulty. From available information, it would appear to be most abundant on an unnamed species of coral (local collectors call it *Alcyon*-type coral). The shells seem to average about 41 mm in length and 7.5 mm in width at the body whorl and outer lip. The specimen illustrated here was collected at Cooktown, Queensland, Australia, living on the coral mentioned above.

2. *Volva (Phenacovolva) brevisrostris* (SCHUMACHER, 1817)

Ess. Nouv. Syst. Vers Test. 1817: 259

(Plate 56, Figure 5)

Syn.: *Ovule birostre* LAMARCK, 1810

Ann. Mus. Hist. Nat. Paris 16: 113

Ovula rosea A. ADAMS, 1854

Proc. Zool. Soc. London 22: 130

Ovula recurva A. ADAMS & REEVE, 1848

Voy. Samarang, Moll., 1848: 21; pl. 6, fig. 3

Cyphoma elongatum A. ADAMS, 1864

J. P. Linn. Soc. London 7: 96

Phenacovolva nectarena IREDALE, 1930

Mem. Queensld. Mus., 10 (1): 85; pl. 9, fig. 6

This species has a wide living range throughout the Pacific region. It is a rather common species along the East Asian coast and the offshore islands, including the Philippines, Taiwan, Ryukyu Islands, and the Japanese island chain, as well as the coast of mainland China; otherwise the distribution of this species is as far east as Hawaii, then south to the Cook Islands, and southwest into the Celebes-Sulu Seas. The shell possesses a characteristic shape, with sharply angled shoulders; a singular

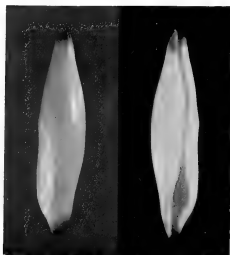


Figure 1
Volva (Phenacovolva) brunneiterma
C. N. CATE, spec. nov. $\times 2\frac{1}{2}$

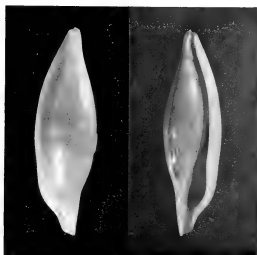


Figure 2
Volva (Phenacovolva) lahainaensis
C. N. CATE, spec. nov. $\times 1\frac{1}{2}$

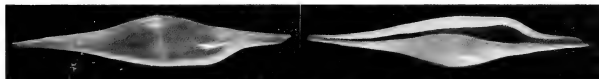


Figure 3
Volva brevirostris (SCHUMACHER, 1817) $\times 2$

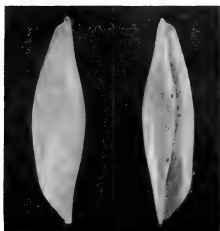


Figure 4
Volva (Phenacovolva) philippinarum
(SOWERBY^{2nd}, 1848) $\times 2\frac{1}{2}$

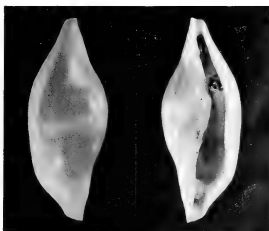


Figure 5
Volva birostris (LINNAEUS, 1758) $\times 1\frac{3}{4}$



shade of beige-grey color; a shorter, broader shell, with shorter, sturdier terminal beaks and with a conspicuous white transverse band of color across the central dorsal area. The shell varies in size, with an average length of 29 mm and an average width of 11.5 mm at the body whorl and lip. The specimen illustrated was collected in 190 feet of water off Lahaina, Maui, Hawaii, living on black coral, the same habitat as one of the species described as new herein.

3. *Volva (Phenacovolva) philippinarum* (SOWERBY¹¹, 1848)

Proc. Zool. Soc. London 1848: 136

(Plate 56, Figure 4)

Syn.: *Volva carpenteri* DUNKER, 1877

Malakol. Blätter 24: 75

Volva maccoyi TENISON-WOODS, 1878

Trans. Roy. Soc. Victoria 14: 56

Volva haynesi SOWERBY¹¹¹, 1889

Journ. Linn. Soc. London 20: 397; pl. 25, figs. 1-2

This is one of the smallest *Volva* species to be considered in this report, with the shell averaging about 21.5 mm in length and 5.5 mm in width. The species seems to range from Japan south through the Ryukyus, Taiwan, the Philippines, the east coast of Australia, and possibly into South Australia [*Volva (Phenacovolva) exsul* (IREDALE, 1935) is probably the same as *V. philippinarum*]. VERCO, of the South Australian Museum, recorded a specimen collected in South West Australia as *Ovula philippinarum* SOWERBY; it had been dredged from 72 fathoms, 40 miles at sea from Eucla. I have not seen this shell and therefore cannot ascertain the correctness of this identification at this time. The Philippine Islands seem to be the center of greatest abundance for this species. The shell is narrow, with an outer lip somewhat flaring anteriorly, with fine transverse dorsal sculpture; it varies in color from pale beige-white to pink. The specimen illustrated is from Kii, Japan.

4. *Volva (Phenacovolva) lahainaensis* C. CATE, spec. nov.

(Plate 56, Figure 2)

Shell narrow, elongately-ovate, subcylindrical, light in weight though strong; body whorl inflated, narrowing abruptly toward the terminals; dorsum transversely sculptured with faint, parallel, zigzag embossed lines adapically and abapically, though lines do not zigzag anteriorly; terminals long, narrow, pinched laterally, both in front and in back, more so to the front; aperture narrow to the rear, widening, becoming openly constricted abapically; left margin rounded, not thickened, right margin on outer lip

thickened, narrowly, sharply, abruptly formed, creating a sharp angle with the body whorl, thus becoming keeled into a distinct carina, which extends entire length of outer lip; fossula primitively formed, subconcave, slightly more so centrally; columella smooth, glossy, with a bifid (almost trifid) first funiculum adapically (see CATE, 1964: pl. 19, fig. 3); shell predominantly translucent orange in color, although the body whorl reflects an overtone of orange-grey; a distinct, deep, rich orange line encircles the shell at the margins, broken only by terminal openings, - on the right side enveloping the sharp marginal angle of the outer lip carina; untoothed, semi-sharp, adaxial edge of outer lip noticeably lighter in color in some specimens; interior of shell, fossula, columella, and interior of terminal channels rich orange color, funiculum a shade lighter.

Type Locality: The specimen was collected alive on black coral in 190 feet of water off the southwest shore of the Hawaiian island of Maui; the specific area is referred to locally as "Lahaina Roads" (20°52' N Lat.; 156°41' E Long.), which may generally be stated as being between Maui and Lanai. SCUBA divers brought the coral to the surface where this and other specimens were easily removed. It was sent to me for identification by Clifton S. Weaver of Lanikai, Oahu, Hawaii.

Type Repository: The holotype will be deposited in the Bernice P. Bishop Museum, Honolulu, Hawaii; it will bear the Malacology Catalogue no. 217597.

Discussion: The holotype of *Volva lahainaensis* is 31.2 mm long and 9.1 mm broad at the outer lip, and 7.3 mm high from ventral to dorsal surface. The shell shows a gently curving aperture, flaring, widening, then abruptly constricting abapically. To my knowledge there are between 5 and 10 specimens known at present; all are from deep water habitats, and all have been collected from black coral. At the present time it is not known whether the species occurs elsewhere in this island chain; future discovery will determine the extent of its range.

This new Hawaiian species appears morphologically distinct from other forms of *Volva*. It differs from another Hawaiian species, *V. brevirostris* (see Plate 56, Figure 5), by its lighter weight, narrower, less sharply angled shoulders, and slimmer overall appearance; by its lack of a central color band; by the intense, dark orange color; and by the presence of a deep, rich orange peripheral line bordering the sides of the shell. Also, *V. brevirostris* appears generally wider and shorter.

Perhaps the most similar form would be that of the color variant of *Volva brevirostris* mentioned as living on the coasts of mainland China and Japan, reported as *Ovula rosea* A. ADAMS, 1854. However, its apparent strong

morphological affinity to *V. breviostris* despite its pinkish coloring seems to separate the two forms. The new Maui species differs from *V. rosea* by being a narrower, more delicate shell; by the absence of the angulate shoulder; by the presence of the distinct funiculum, by the intense orange coloring, and particularly by the presence of the encircling orange line.

5. *Volva (Phenacovolva) brunneiterma* C. CATE, spec. nov.

(Plate 56, Figure 1)

Shell delicate, though strongly constructed, well formed, elongately narrow; dorsal surface smooth (except for minute, barely visible, longitudinal growth lines), untextured; funiculum absent; terminals minutely flaring; aperture exceedingly narrow, opening broadly at constriction of outer lip anteriorly; left margin not thickened, rounded; right margin without callus, lip flatly thickening adaxially, then rolling and curving upward within; fossula smooth, not impressed; primary shell color milk-white; terminal ends dark brown, with a pale brush of yellow-brown abapically the length of terminal ridge area.

Type Locality: The specimen was found in the subtidal waters off Siasi Island, Sulu Sea ($5^{\circ}32'N$ Lat.; $120^{\circ}52'E$ Long.). It was collected in 1960, and was sent to me by Mr. Fernando G. Dayrit, Manila, Philippines, for identification.

Type Repository: The holotype, a unique shell, will be deposited in the California Academy of Sciences Geology Department Type Collection, where it will bear the number 13161.

Discussion: The holotype of *Volva brunneiterma* is 20.3 mm long, 4.7 mm broad at the left margin and outer lip,

and 4.2 mm high. This new species has been confused with *V. philippinarum*, which it vaguely resembles; however, it differs radically by being a narrower shell; by possessing a nearly closed aperture; by the compact outer lip (not flaring as in *V. philippinarum*); by having a smooth dorsal surface, although there are very faint growth lines longitudinally (as compared with the horizontally sculptured, evenly spaced lines of the latter species); by the outer lip being peculiarly crimped and constricted anteriorly; by the dark brown coloring at the terminal extremities. Because of the lack of adequate material, the distribution of this new taxon is at present unknown.

The conspicuous dark brown terminals are a characteristic color feature in this species, providing a means for easily separating it from others. Therefore it seemed appropriate to use this distinguishing character as a basis for its specific name, which is derived from the Latin word *brunneus* (dark brown) and the Greek *terma* (for the shell terminals); hence the name *brunneiterma*.

I want to thank Jean Cate for the excellent photographic work, and Dr. Takeo Susuki for the film processing. I also want to thank Dr. Franz Alfred Schilder for his considerations of the new species.

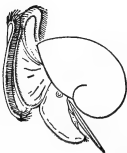
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1932. The living species of Amphiperatinae. *Proc. Malacol. Soc. London* 20 (1): 46-64; pls. 3-5 (78 figs.)



Zoogeographical Studies on Living Cowries

BY

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

(1 Map)

FOUR YEARS AGO I published a systematic list of species and races of living cowries with exact indications of the then known geographical distribution (SCHILDER, 1965). In the intervening 4 years several new cowrie species have been discovered and enthusiastic collectors have enlarged the knowledge of occurrence by filling small gaps in evidently continuous distribution as well as by slightly extending the known boundaries of inhabited areas.

However, in present times zoogeographers must be very careful in taking localities for granted even if the determination can be checked; for since World War II soldiers and tourists often have thrown away shells in areas other than where they had collected them, seamen emptied ballast tanks on remote coasts, and dealers and natives indicated wrong localities to gain higher prices. Therefore the Central Pacific species collected as beach shells on the West Coast of America have been rejected in the present paper as no living specimens has ever been collected here. Even single living specimens cannot exclude the possibility of having been introduced by man (for references see SCHILDER, 1965, p. 171).

The present paper does not consider often uncertain details but aims to give a survey about the general rules concerning the distribution of living cowries and to compare similar distributions in species of different descent and in taxa of different evolutionary status.

Its aim is to encourage similar investigations in other groups of marine mollusca.

TAXONOMY

Species and subspecies have been treated in the same way as the classification of these taxa is often dubious and the rules of distribution seem to be hardly influenced by the present phase of evolution of species.

Intraspecific taxa have been considered to be of subspecific rank (prospectives and subspecies) only if they are well separable by morphological characters without knowledge of the habitat of the specimens; infraspecies have been treated only if their distribution is discontinuous; clines and local mutants mostly have been ignored (see SCHILDER, 1966).

The customary citation of generic names does not make clear the exact position of the species in Cypraeidae to a reader not well acquainted with the phylogenetical systematics of the family. Therefore I prefer to replace the generic names by 3-digit numbers according to my paper on the generic classification of cowries (SCHILDER, 1968); the first figure indicates the subfamily, the second indicates the tribus (infrafamily), the third indicates the (in 1968 not numbered) genus; subgenera have been ignored so that 4-digit numbers can be avoided.

The figures indicate the following taxa of living Cypraeidae:

4	Bernayinae	62	(Cypraeovulini)
42	(Bernayini)	622	<i>Cypraeovula</i>
421	<i>Bernaya</i>	623	<i>Notocypraea</i>
424	<i>Zoila</i>	624	<i>Umbilia</i>
426	<i>Siphocypraea</i>	63	(Erroneini)
5	Cypraeinae	631	<i>Erronea</i>
51	(Cypraeini)	632	<i>Notadusta</i>
512	<i>Tirona</i>	633	<i>Palnadusta</i>
513	<i>Macrocypraea</i>	634	<i>Bistolida</i>
514	<i>Mauritia</i>	635	<i>Ovatipsa</i>
515	<i>Talparia</i>	636	<i>Cribrarula</i>
516	<i>Cypraea</i>	7	Erosariinae
517	<i>Lyncina</i>	71	(Pustulariini)
52	(Lurini)	711	<i>Pustularia</i>
522	<i>Chelycypraea</i>	714	<i>Propustularia</i>
523	<i>Luria</i>	72	(Erosariini)
6	Erroneinae	721	<i>Monetaria</i>
61	(Zonariini)	722	<i>Naria</i>
612	<i>Schilderia</i>	723	<i>Erosaria</i>
613	<i>Zonaria</i>	724	<i>Staphylaea</i>
		725	<i>Nucleolaria</i>

The citing of authors of specific names in the text might distract the reader's concentration on the zoogeographical facts; these names can be found in the appended list of living cowries.

ZOOGEOGRAPHICAL CLASSIFICATION

There is a surprising symmetry in the natural arrangement of littoral territories with regard to the distribution of living cowries.

Hemispheres

The boundaries between the western and eastern hemispheres lie in the eastern Pacific between Easter Island and the Galápagos Islands, about at Walvis Bay in South West Africa, and in the Suez Canal. They are never crossed by any living cowrie species.

For the Indopacific 523 *isabella* and its West American representative 523 *mexicana* should be regarded as distinct species rather than as conspecifics, and the pair 523 *lurida* (Mediterranean) and 523 *pulchra* (Red Sea) is still far less allied each to the other, as these species belong to different subgenera.

Even on the generic level the hemispherical separation becomes evident as only 3 genera are common to both hemispheres, viz. 523 (*Luria*), 612 (*Schilderia* the Pacific species of which possibly should be separated generically), and 723 (*Erosaria*); 5 genera (425, 512, 513 613, 714) are restricted to the western hemisphere, whereas the remaining 21 genera live in the eastern hemisphere only.

On the tribus level the separation of the hemispheres is much reduced as 6 tribes occur in both hemispheres and only 2 (62, 63) are restricted to the eastern one. All 4 subfamilies live in both hemispheres.

Latitudinal Zones

In both hemispheres one can distinguish a broad tropical zone along the equator and two less extended and usually less warm marginal zones accompanying it in the north and in the south.

Many tropical cowries extend far beyond the equatorial zone into remote areas, while only few obviously northern or southern taxa have also been discovered in scattered localities situated in the equatorial belt.

In the two southernmost regions inhabited by cowries live 4 genera all species of which are restricted to these relatively cold waters.

They are 622 (*Cypraeovula*) in South Africa and 424 (*Zoila*), 623 (*Notocypraea*), and 624 (*Umbilia*) on the south coast of Australia. In these 4 genera there is a curious splitting into many allied sympatric species, *Umbilia* excepted in which the splitting into many south Australian species partially of unique features (624 *gastroplax* McCov) took place in Tertiary times, as it was also in *Zoila* (424 *platypya* McCov, 424 *gigas* McCov). Along the other borders of the territory inhabited by living cowries no similar unusual fauna will be found: the splitting of 613 (*Zonaria*) in Senegal and of 612 (*Schilderia*) in Japan is far less striking.

Longitudinal Districts

Moreover, in either hemisphere 3 longitudinal districts can be distinguished: a western, a central, and an eastern district.

Their boundaries are caused by the present coasts of the continents.

In the western hemisphere the 3 districts are distinctly separated with regard to the cowrie fauna: there are unsurmountable boundaries between West America, East America, and West Africa (the Mediterranean Sea included), as no cowrie species crosses the Panama Canal nor the halfway line along the Atlantic.

For the West American 513 *cervinetta* and the East American 513 *cervus* can be well separated at least as conspecifics, and the intermediate status of 723 *spurca sanctaehelenae* between the East American 723 *acicularis* and the West African 723 *spurca* needs confirmation.

In the eastern hemisphere, however, the 3 longitudinal districts gradually pass each into the other as many cowrie species occur far beyond the borders of the western half of the Indian Ocean, the central district from Japan to Australia, and the small islands of the Central Pacific.

There are plenty of species ranging from East Africa to Polynesia, but there are also many species limited to one of these 3 districts, e.g., 633 *diluculum* in the West, 633 *lutea* in the middle, and 517 *schilderorum* in the East.

Central and Peripheral Regions

From the combination of latitudinal zones and longitudinal districts a net-like pattern results in which a central region is surrounded by at least 9 peripheral regions in either hemisphere. In the more extended eastern hemisphere the central region is far more spacious than the peripheral regions which look like appendices to the vast Indopacific region. The 4 corner regions (South Africa, Red Sea plus Persian Gulf, Tuamotu, Hawaii) are more important faunistically than the border regions between them, Japan and the south coast of Australia excepted.

Among the many cowrie species which live across the tropical Indopacific from East Africa to Polynesia rather few species inhabit also the 4 corners - Natal, Red Sea, Tuamotu, Hawaii: 514 *mauritanica*, 515 *talpa*, 517 *lynx*, 517 *carneola*, 523 *isabella*, 721 *moneta*, 723 *helvola*, 725 *nucleus*; however, only 517 *carneola*, 523 *isabella*, 721 *moneta*, and 723 *helvola* reach the south coast of South Africa and the most widely spreading cowrie species 517 *carneola* reaches also the Persian Gulf, but none of them reaches the south coast of Australia (the most western parts excepted) nor New Zea-

land. The other widely spread species are absent in at least one corner region, or replaced there by closely allied, but well distinguishable species or races.

In some species there is a tendency to produce similar clines along the whole periphery of the inhabited area.

So, e.g., in 514 *arabica* (SCHILDER, 1961) and 516 *tigris* the general size increases distinctly from an Indopacific center to all border areas, and in 631 *errones* (SCHILDER & SCHILDER, 1968) several characters show gradual peripheral changes.

CONTINUOUS DISTRIBUTION

The primary mode of distribution of a monophyletic natural taxon undoubtedly is continuous.

The inclusion of very small areas in which a taxon cannot live on account of unsuitable environments does not contradict the term 'continuity of distribution'.

Monotypic Taxa

Continuous distribution can be observed in taxa restricted to very small areas as well as in species which range from East Africa to Polynesia without developing morphologically distinguishable races.

Examples of such Indopacific species are 514 *mauritiana*, 517 *vitellus*, 633 *asellus*, 634 *teres*, 721 *moneta*, 725 *nucleus*. In such species we have tried 30 years ago (SCHILDER & SCHILDER, 1938/1939) to distinguish widely distributed geographical races (infraspecies) by the sum of variable minute characters; the distribution of these minor taxa is continuous and rather coincides with similar taxa separated by distinct gaps in discontinuous Indopacific species. However, as we have examined far more populations of these species for these 30 years, we now doubt the reality of many infraspecies and we consider them to represent indistinct clines at most.

In some rare species the few known localities seem to be separated by larger vacant areas, but future research most probably will fill these gaps.

So, for instance, 633 *gracilis* and 633 *saualae* evidently inhabit the same territory from Japan to Australia and from the Gulf of Bengal to the westernmost Pacific; within this territory the common 633 *gracilis* has been found in 36 "areas" (according to SCHILDER & SCHILDER, 1965, p. 173, paragraph 6), but the rare 633 *saualae* so far only in 13.

The size of the inhabited territory of a species varies from 1 to 80 "areas" as distinguished by SCHILDER (1965, pp. 173-175, to which the area "54 a: Auckland and North New Zealand, 10-16 centigrades" should be added).

Many very rare species are known from one area only, and even 631 *uredenburgi* of which many hundred beach shells have been collected in southern Java, just reaches the border of a second area. The most widely distributed species is the Indopacific 517 *carneola* which inhabits at least 80 areas.

Even if the arrangement of coasts and islands would allow a rather circular expansion of the boundaries of a species, the real distribution often consists in a rather narrow band longitudinally or latitudinally.

Rather circular areas are inhabited, e.g., by 723 *boivini*, 631 *ovum*, and 631 *errones* (all 3 in Malaysia, but with increasing diameter), 514 *immanis* (western Indian Ocean), 631 *bregeriana* (Melanesia), and 634 *goodallii* (Polynesia). Linear distributions are either longitudinal as in 613 *robertsi* in West America and 512 *stercoraria* in West Africa (both avoiding the off-shore islands), 631 *felina* and 723 *marginallii* on the west coast of the Indian Ocean, 631 *xanthodon* in East Australia (common on the coast, rare on the off-shore islands, absent from Lord Howe Islands), 723 *guttata* on the west coast of the Pacific, and 725 *granulata* (*casiaui* included) in Polynesia; or latitudinal as 426 *mus* along the north coast of South America, 723 *gangranosa* in the northern Indian Ocean, 723 *maturata* (*mariae* included) in the northern Pacific, and 636 *fischeri* on its southern border; the distribution of 631 *pallida* and 723 *ocellata* could be called more oblique as these species range from the Persian Gulf to southern Malaysia.

Polytypic Taxa

Continuous distribution is necessary in species developing clines especially in less warm areas (SCHILDER, 1966, p. 184).

Thus 723 *caputserpentis* gradually passes from the tropics into the South-East-Australian cline *caputangui*, 723 *erosa* in the same region into the cline *pulchella*, and 723 *helvola* into the South-African cline *meridionalis*.

But continuous distribution often can be found also in species that can be divided into 2 or more morphologically well distinguishable geographical subspecies or even in pairs of allied species constituting a superspecies (SCHILDER, 1966, p. 182); their territories are separated along a common boundary line which mostly runs longitudinally.

This common case may be illustrated by pairs of allied taxa which have been arranged according to their boundary line being displaced from west to east (SCHILDER, 1965, pp. 173-175). The first named partner occupies the larger territory or is obviously the more primitive taxon, the second may be called peripheral; an asterisk (*) marks pairs of undoubted specific rank; for the inhabited regions see the appended list or more accurately in SCHILDER, 1965 (pp. 176 to 183):

- * 523 *isabella/mexicana*
- * 613 *annettae/spadicea*
- 513 *cervineta/cervus*
- * 523 *cinerea/lurida*
- 723 *acicularis/spurca*
- 631 *listeri/felina*
- 723 *redimita/lamarckii*
- 723 *erosa/nebrites*
- * 634 *stolida/erythraeensis*
- * 723 *marginalis/ocellata*
- * 723 *miliaris/redimita*
- * 631 *pallida/vredenburgi*
- 631 *cylindrica/iowerebyana*
- * 424 *thersites/friedii*
- * 624 *hesitata/armeniaca*
- 631 *subviridis/dorsalis*
- 631 *walkeri/bregeriana*
- 633 *humphreysii/lutea*
- 517 *schilderorum/kuroharai*
- 723 *mariclae/maturata*
- * 723 *caputserpentis/caputdraconis*
- * 723 *scarabaeus/engleri*
- 725 *granulata/cassini*

Also the tripartite species can be added:

- 514 *arabica/immanis/grayana*
- 631 *adusta/onyx/melanesiae*

However, in some pairs the adjacent territories do not meet along a common boundary line, but they distinctly overlap in a narrow zone, in which occasionally hybrids may be observed:

- * 613 *zonaria/picta*
- 613 *pyrum/petitiana* (hybrids? "*senegalensis* SCHILDER")
- * 516 *tigris/pantherina* (hybrids)
- * 517 *vittellus/camelopardalis*
- * 723 *lamarckii/turdus*
- 723 *miliaris/eburnea* (hybrids)

Rarely is the continuous area of Indopacific distribution composed of more than 3 taxa; on the subspecific level such series of taxonomic units may be classified as clines, but on a higher level they become real subspecies or even well separable species which replace each other along definite boundary lines or slightly overlap at their borders.

In 523 *isabella* 3 clines and a border species can be distinguished by the black terminal spots increasing from west to east: * *isabella*, *lekalekana*, *controversa*, and * *mexicana*. On the other hand, in the series 723 * *lamarckii*, *redimita*, * *miliaris*, *eburnea* the brown pigmentation decreases from west to east.

The areas of peripheral species often become almost covered by widely spread central allies so that a very small corner remains for the sole presence of the former.

So, for instance, 523 *pulchra* lives also in the Persian Gulf where the Indopacific 523 *isabella* is absent, while in the

whole Red Sea both live side by side; 633 *artuffeli* extends in Japan farther to the north than its widely distributed ally 633 *clandestina*; and 634 *subterres* seems to be an analogous taxon in the Tuamotu Islands with regard to its Indopacific ally 634 *terres*.

In rare extreme cases the area of the peripheral species has been quite covered by its widely distributed ancestor species, so that both become sympatric in the whole territory of the former.

Thus 513 *cervus* is restricted to the northernmost border areas of its ancestor 513 *zebra*, and 515 *exusta* is restricted to the southern Red Sea, while the Indopacific 515 *talpa* crosses it as far as Sinai.

WAYS TO DISCONTINUITY

In some latitudinally or longitudinally tripartite species the two border taxa are more similar to each other than to the immediately adjacent central taxon; there is the question whether the two border taxa are farther developed in a parallel way than the older central taxon, or, on the contrary, the latter is the younger taxon arisen in the central area and pushing back the border halves of the original taxon. Morphological aspects seem to favor the latter interpretation.

Such cases may be illustrated latitudinally by 633 *gracilis* of which the northern and southern clines *japonica* and *macula* are hardly distinguishable, while the central *gracilis* is different at least statistically; the Mediterranean 613 *pyrum* and the hardly separable unique *angolensis* from western Angola are connected by the morphologically distinct tropical *petitiana*. Longitudinally the western 631 *adusta* becomes separated from the very similar *melanesiae* by the central *onyx* differing in color, at least, and the western 635 *variolaria* from the eastern *chinensis* by the north Indian *coloba*. On the specific level one could add 523 *isabella* between *pulchra* and *mexicana*, both with large terminal spots and brown pigment on the teeth or margins, respectively; and possibly also 514 *eglantina* between *histrio* and *maculifera*.

The rare cases of several minor taxa of a species surrounding the often overlapping central territory occupied by another less closely related species may belong to the same category.

The discontinuous races of 631 *pulchella* (viz. *vaysierei*, *pericalles*, *pulchella*, *novaebrittanniae*) and of 723 *cernica* (viz. *cernica*, *viridicolor*, *tomlini*, *maturata*, *mariclae*) seem to be grouped around the central territory occupied by 631 *pyriformis* and 723 *labrolineata*, respectively.

In some few cases of now discontinuous distribution the at present existing gap can be filled by extinct ancestors so that the distribution becomes continuous for the scientist familiar with both living and fossil species.

The rare Pleistocene 631 *semicostata* SCHILDER from Java seems to connect the living races of *pulchella* just mentioned, and the recent *pyriformis* which is more frequently represented in the same beds (*propyriformis* SCHILDER). The now discontinuous genus 613 (*Zonaria*) becomes continuous by considering fossil species, as the living species 613 *zonaria* (West Africa) and 613 *aequinoctialis* (plus *annettae*, both in West America) were connected in Miocene times by the East American 613 *raymondobertsi* PILSBRY and 613 *boudenensis* PILSBRY. Possibly one could add on a still higher level the 3 relic species of 421 *Bernaya*, viz. *teulerei* (Arabia), *fultoni* (South Africa), and *catei* (West Australia) which live about in corners of the eastern Tethys region occupied by their many Eocene ancestors in 421 (*Bernaya*); even 426 *mus* whose Neogene ancestors were widely distributed in North and South America could be regarded as a fourth corner relic of the vast distribution of 42 (Bernayini) along the Paleogene Tethys Sea.

DISCONTINUOUS DISTRIBUTION

According to the generally adopted rules of evolution and dispersion of all living beings there is no primary discontinuous distribution, as all taxa originated from single populations inhabiting a small continuous territory. Therefore the discontinuity is always secondary, in cowries 1. if members of a population have been displaced

- a) naturally in larval stages by currents, etc. or
- b) accidentally by man with his ships and hydroplanes to remote areas where the species could gain a footing; or

2. if the discontinuity is the result of extinction of connecting taxa in past geological times.

The discontinuity also may be apparent only if it is caused by still insufficient knowledge of recent faunas and if there is some hope to discover geographically connecting taxa especially in the as yet less explored deep waters.

The distribution of living cowries is rather well known, though future research undoubtedly will fill many gaps and correct many boundary lines. So the specialist is more surprised by the relatively large number of evidently real discontinuities in distribution revealed by critical examination of all available indications of habitat.

Some isolated discoveries of single specimens often said to have been collected alive in remote areas will be excluded from the following considerations; they need further confirmation, or may rely on specimens accidentally introduced by man. Such cases include 631 *errones* and 723 *miliari* in East Africa, 514 *maculifera*, 517 *nivosa*, and 631 *barclayi* in Lemuria, etc.

There are two prevalent directions of geographical discontinuity in living cowries:

1. latitudinal: two allied taxa live in the north and in the south of an equatorial belt in which no related taxon occurs;
2. longitudinal: two related taxa live in the west and in the east along the equatorial belt, but they are separated by a central region uninhabited by any related taxon.

Of course, latitudinal discontinuities refer only to pairs of taxa living in about the same longitudinal district. The only non-equatorial longitudinal discontinuity exists along southern Asia between 631 *pericalles* (Persia) and 631 *pulchella* (China).

Latitudinal Discontinuities

Some pairs of taxa, from allied species to hardly discernible infraspecies, live in opposite areas of the northern and southern zone without being connected geographically by a related equatorial taxon. One could call this fact "bipolarity" in a broad sense, as it probably is caused by parallelism of the areas concerning temperature. Therefore one must bear in mind that future research may supply connecting links in very deep waters of the equatorial zone. Such bipolarity has been observed almost only in 6 (*Erroneinae*).

An accumulation of such "bipolar" pairs recently has been discovered to exist in the Japanese and East Australian faunas:

612 *langfordi* - *moretonensis*

* 612 *hirasei* - *queenlandica*

631 *hungerfordi* - *coucomi*

631 *piscatorum* - *subviridis*

* 632 *katsuae* - *hartsmithi*

723 *maturata* - *tomlini*

but it occurs also in the central Pacific (Hawaii - Melanesia):

634 *latior* - *rashleighana*

636 *gaskoini* - *fischeri*

as well as in West Africa (Mediterranean - Angola):

612 *achateidea* - *inopinata*

613 *pyrum* - *angolenis* (here the gap is filled by the less closely allied *petitiana*, see above)

and in West America (Gulf of California - Ecuador):

613 *annettae* - *aequinoctialis*.

In a few pairs a northern or a southern taxon is replaced by an allied cowrie in the equatorial zone; however, as the boundaries of the equatorial partners are still uncertain on account of their rarity, these cases also may be interpreted as continuous distribution:

631 *pulchella* (China) - *novaebritanniae* (Melanesia)

631 *xanthodon* (East Australia) - *fernandoi* (Philippines)

633 *hammondae* (Australia) - *raysummersi* (Malaysia)

one could add from the past:

* 424 *friendii* (West Australia) – *kendengensis* SCHILDER (Pleistocene of Java)

* 613 *aequinoctialis* (Ecuador) – *zonaria* (West Africa); the gap in East America is filled by Tertiary species (see above).

Longitudinal Discontinuities

In many widely distributed taxa a distinct discontinuity between a western and an eastern branch can be observed, comparable to the north-southern "bipolarity" discussed above. This "bicentricity", however, cannot be explained by climatic reasons, but we must suppose that a continuously distributed species has become extinct in its central territory so that the geographically separated halves eventually could develop in different ways.

In a few cases a slightly less closely allied taxon still fills the area between the two very similar border taxa or an extinct central taxon has been discovered as fossil (see above).

In the western hemisphere the longitudinal range of species is too small so that such longitudinal discontinuity can be shown only in

In the eastern hemisphere, however, many discontinuities have been discovered by accurate research on trustworthy localities. These discontinuities occur chiefly in widely distributed pairs of rather common species separating an Indian and a Pacific taxon. The central area devoid of any member of the pair is not identical in any of the cases, but it changes from India to Central Malaysia.

In the following lists the vacant area has been named between arrow heads (> <) separating the first named western taxon and its eastern ally.

Such discontinuities occur on the infraspecific level, i. e. the two partners cannot be distinguished morphologically from each other; nevertheless one must expect that the partners separated for a long time have developed hereditary differences by different selection of genes, which possibly could be discovered by statistical methods:

631 <i>amabilis</i>	>	India	< <i>walkeri</i>
724 <i>interstincta</i>	>	Andamans-Sumatra	< <i>limacina</i>
635 <i>variolaria</i>	>	Ceylon-Borneo	< <i>chinensis</i>
522 <i>ingens</i>	>	West and Central Malaysia	< <i>testudinaria</i>
711 <i>lemurica</i>	>	southern Malaysia	< <i>childreni</i>
514 <i>dispersa</i>	>	central Malaysia	< <i>depressa</i>
723 <i>poraria</i>	>	central Malaysia	< <i>scarabaeus</i>
631 <i>adusta</i>	>	Malaysia	< <i>melanesiae</i>

The differences have been intensified to true subspecies level in:

514 <i>alga</i>	>	Maldives, India	< <i>mapa</i> (incl. <i>geographica</i>)
633 <i>notata</i>	>	India	< <i>gracilis</i>
633 <i>chrysalis</i>	>	India, Sumatra	< <i>microdon</i>
631 <i>pericalles</i>	>	India, South Malaysia	< <i>pulchella</i>
514 <i>scurra</i>	>	central Malaysia	< <i>indica</i>

Rarely pairs of equal specific rank occur:

* 723 <i>macandrewi</i>	>	India to Celebes	< <i>beckii</i>
* 514 <i>histrion</i>	>	Malaysia, New Guinea	< <i>maculifera</i>

To these examples of discontinuous distribution one can add 2 pairs of species, each pair living in restricted parts of the Indo-Pacific:

* 517 <i>broderipii</i>	>	Lemuria	< <i>nivosa</i> in the Indian Ocean and
* 723 <i>boivinii</i>	>	Micronesia	< <i>ostergaardi</i> in the Pacific

SYSTEMATIC LIST

These general observations may be followed by a systematic list of living species, (p) prospecies, (s) subspecies, (c) clines, (i) infraspecies, and (m) local mutants (SCHILDER, 1966). The present list shows far less details in distribution than the list published 4 years ago (SCHILDER, 1965, pp. 176-183), but it is a clearer survey of the general distribution over the greater regions.

These "regions" have been designated in the former list (SCHILDER, 1965) by 2-digit numbers and 3 capital letter-abbreviations; for augmenting the clarity in a more concentrated table I now prefer to return to the 1-capital system used in a previous paper (SCHILDER, 1941 with partially modified regional capitals and limits). As there are 30 regions at least, some capitals must be used twice; therefore the less numerous regions of the western hemisphere have been printed in *italics>*, and the western species have been marked with □.

The following alphabetical list of regions contains the abbreviation (one capital letter), the name of the region, and its former designation with 2 digits. The Map shows the boundaries of these regions.

WESTERN HEMISPHERE

A Antillean 81	H St. Helena 85
B Brazilian 86, 73	L Lusitanian 96
C Californian 89, 35	M Mediterranean 95
E Ecuadorian 87	P Panamian 88
F Floridian 82	S Senegalese 83
G Guinean 84	

EASTERN HEMISPHERE

A East African 18	M Malayan 48
C South African 17	N New Guinean 41
D Dampierian 15	P Persian 12
E Erythraean 19	Q Queenslandian 47
F Fijian 46	(including 54h = Lord Howe Is.)
G Guam (Micronesian) 42	R Rapanuan 45
H Hawaiian 43	S Sumatran 14
I Indian 13	T Tahitian 44
J Japanese 49, 37	V Victorian 58
L Lemurian 11	Z Zealandian 54

(h excluded)

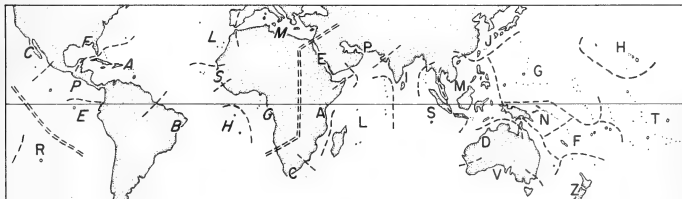
In the list of valid taxa of living cowries the regions inhabited by each taxon have been enumerated according to my previous arrangement (SCHILDER, 1965, pp. 173 to 175) as follows:

western (□): C P E F A B M L S G H
eastern: C A L E P I S D V Z Q F N M J G T R H

If it appears to be necessary to emphasize the restriction to a part of a region, the nine digits used in my former paper (SCHILDER, 1965, p. 171) will be used as exponents:

9 = NW 0 = N 3 = NE
8 = W 1 = central 4 = E
7 = SW 6 = S 5 = SE

The sign || marks greater discontinuities within the taxon.



CYPRAEIDAE GRAY, 1824

- 4 Bernayinae SCHILDER, 1927
- 42 (Bernayini SCHILDER, 1927)
- 421 *Bernaya* JOUSSEAUME, 1884
teulerei (GAZENAVETTE, 1846) E⁶ P¹
fultoni (SOWERBY, 1903) C²
catei SCHILDER, 1963 D⁷
- 424 *Zoila* JOUSSEAUME, 1884
decipiens (SMITH, 1880) D¹⁷
venusta (SOWERBY, 1846) D¹ V⁸
thersites (GASKOIN, 1849) V¹
friendii (GRAY, 1831) D⁷ V⁸
marginata (GASKOIN, 1849) D⁷ V⁸
rosselli (COTTON, 1948) V⁹
- 426 *Siphocypraea* HEILPRIN, 1887
 □ *mus* (LINNAEUS, 1758) A⁶
- 5 Cypracinae GRAY, 1824
- 51 (Cypracini) GRAY, 1824
- 512 *Trona* JOUSSEAUME, 1884
 □ *stercoraria* (LINNAEUS, 1758) S⁴ G
- 513 *Macrocypraea* SCHILDER, 1930
 □ *zebra* (LINNAEUS, 1758) F A B
 □ *cervus* (LINNAEUS, 1771) F A¹
 □ - (p) *cervinetta* (KIENER, 1843) C⁴ P E
- 514 *Mauritia* TROSCHER, 1863
valentia (PERRY, 1811) Q² N²
mappa (LINNAEUS, 1758) D³ Q² F N M J⁶ G T
 - (c) *geographica* SCHILDER & SCHILDER, 1933 S
 - (s) *alga* (PERRY, 1811) A¹ L E⁶
arabica (LINNAEUS, 1758) I S D Q F N M J G T³
 - (m) *gibba* COEN, 1949 M⁸
 - (s) *immanis* SCHILDER & SCHILDER, 1939
 C² A L
grayana SCHILDER, 1930 A¹ E P I⁹
eglantina (DUCLOS, 1833) S² D Q F N M J⁶ G
histro (GMELIN, 1791) A L I S D
maculifera SCHILDER, 1932 (L¹?) || F¹ J⁶ G T H
depressa (GRAY, 1824) F N M³ J G T
 - (i) *dispersa* SCHILDER & SCHILDER, 1939
 A¹ L¹ I S
mauritiana (LINNAEUS, 1758)
 (C²) A L E⁶ I S D Q F N M J G T H
scurra (GMELIN, 1791) A L I S (D²)

- (s) *indica* (GMELIN, 1791)Q F N M⁴ J⁶ G T H

- 515 *Talparia* TROSCHER, 1863
talpa (LINNAEUS, 1758)
 C² A L E P⁶ I S D Q² F N M J G T H
exusta (SOWERBY, 1832) E⁶
- 516 *Cypraea* LINNAEUS, 1758
tigris (LINNAEUS, 1758)
 C² A L E¹ I S D Q² F N M J G T
 - (c) *schilderiana* CATE, 1961 T¹ H
pantherina SOLANDER, 1786 E
- 517 *Lyncina* TROSCHER, 1863
aurantium (GMELIN, 1791) F N M³ G T⁶
broderipii (SOWERBY, 1832) C¹ (L²?)
nivosa (BRODERIP, 1827) (L²?) I¹ S⁹
leucodon (BRODERIP, 1828) (L²?) M³
argus (LINNAEUS, 1758)
 A¹ L I S D Q² F M J⁶ G T²
porteri (CATE, 1966) M³ J⁷
lynx (LINNAEUS, 1758)
 C² A L E I S D Q F N M J G T H
vitellus (LINNAEUS, 1758)
 C A L I S D V⁹ Z¹ Q F N M J G T H
camelopardalis (PERRY, 1811) E⁶
reevei (SOWERBY, 1832) V⁸
ventriculus (LAMARCK, 1810) F N M³ G T
schilderorum (IREDALE, 1939) F G T H
 - (s) *kuroharai* (KURODA & HABE, 1961) J
subcidentata (GRAY, 1824) H
carneola (LINNAEUS, 1758)
 C A L E P I S D Z¹ Q F N M J G T H
 - (m) *titan* SCHILDER & SCHILDER, 1962 A L⁷
 - (m) *leviathan* (SCHILDER & SCHILDER, 1937) H
- 52 (Lurini) SCHILDER, 1932
- 522 *Chelycypraea* SCHILDER, 1927
testudinaria (LINNAEUS, 1758)
 D Q F N M³ J G T
 - (i) *ingens* SCHILDER & SCHILDER, 1938 A¹ L I⁶
- 523 *Luria* JOUSSEAUME, 1884
tessellata (SWAINSON, 1822) H
pulchra (GRAY, 1828) E P⁸
isabella (LINNAEUS, 1758) C A L E I⁶
 - (c) *lekalekana* (LADD, 1934)
 S D Z¹ Q F N M J G T
 - (c) *controversa* (GRAY, 1824) H
 □ *mexicana* (STEARNS, 1893) C¹ P⁸ E⁸
 □ *cinerea* (GMELIN, 1791) F A B
 □ *lurida* (LINNAEUS, 1758) M L S G H

- 6 Erroncinæ SCHILDER, 1927
- 61 (Zonariini) SCHILDER, 1932
- 612 *Schilderia* TOMLIN, 1930
- *achatidea* (SOWERBY, 1837) M⁶
 - - (i) *inopinata* SCHILDER, 1930 G⁶
 - langfordi* (KURODA, 1938) J
 - (i) *moretonensis* SCHILDER, 1965 Q¹
 - hirasei* (ROBERTS, 1913) J
 - queenslandica* SCHILDER, 1966 Q¹
 - teramachii* (KURODA, 1938) J⁵
 - midwayensis* (AZUMA & KUROHARA, 1967) H⁶
- 613 *Zonaria* JOUSSEAUME, 1884
- *gambiensis* (SHAW, 1909) S⁴
 - *zonaria* (GMELIN, 1791) L⁵ S⁴ G
 - *picta* (GRAY, 1824) S
 - *sanguinolenta* (GMELIN, 1791) S⁴
 - *pyrum* (GMELIN, 1791) M L S⁴
 - - (i) *angolensis* (ODHNER, 1923) G⁶
 - - (p) *petitiana* (CROSSE, 1872) S⁴ G¹
 - *annettae* (DALL, 1909) C⁴
 - - (p) *aequinoctialis* SCHILDER, 1933 E⁴
 - *spadicea* (SWAINSON, 1823) C⁶
 - *roberti* (HIDALGO, 1906) C⁴ P⁴ E⁴
 - *arabacula* (LAMARCK, 1810) C⁴ P⁴ E
 - *nigropunctata* (GRAY, 1828) E
- 62 (Cypraeovulini) SCHILDER, 1941
- 622 *Cypraeovula* GRAY, 1824
- fuscobrunnea* (SHAW, 1909) C⁶⁶
 - fuscodentata* (GRAY, 1825) C⁶
 - cohenae* (BURGESS, 1965) C⁶
 - algoensis* (GRAY, 1825) C⁶
 - edentula* (GRAY, 1825) C
 - amphithales* (MELVILL, 1888) C
 - capensis* (GRAY, 1828) C
- 623 *Notocypraea* SCHILDER, 1927
- pulicaria* (REEVE, 1846) V⁸
 - bicolor* (GASKOIN, 1849) V⁴¹
 - (c) *reticulifera* (SCHILDER, 1924) V⁸
 - (s) *occidentalis* IREDALE, 1935 V⁹
 - piperita* (GRAY, 1825) V Q⁶
 - (c) *comptonii* (GRAY, 1847) V⁴¹
 - (m) *casta* SCHILDER & SUMMERS, 1963 V⁴
 - declivis* (SOWERBY, 1870) V⁴
 - angustata* (GMELIN, 1791) V⁴
- 624 *Umbilia* JOUSSEAUME, 1884
- armeniaca* (VERCO, 1912) V¹
 - hesitata* (IREDALE, 1916) V⁴ Q⁶¹
- 63 (Erroncini) SCHILDER, 1927
- 631 *Erronea* TROSCHER, 1863
- walkeri* (SOWERBY, 1832) S D Q M J G⁸
 - (i) *amabilis* (JOUSSEAUME, 1881) L¹²
 - (p) *bregeriana* (CROSSE, 1868) F⁸ N⁴
 - pyriformis* (GRAY, 1824) I⁴ S⁸ D Q¹ M
 - pulchella* (SWAINSON, 1823) M²³ J⁶
 - (i) *vayssierei* SCHILDER & SCHILDER, 1938 E⁶
 - (s) *pericalles* (MELVILL & STANDEN, 1904) P⁸
 - (s) *novaebritanniae* SCHILDER & SCHILDER, 1937 F¹ N⁴
- hungerfordi* (SOWERBY, 1888) J¹
 - (i) *coucomi* SCHILDER, 1964 Q¹
 - barclayi* (REEVE, 1837) C² (L²?)
 - xanthodon* (SOWERBY, 1832) Q
 - (p) *fernandoi* CATE, 1969 M³
 - vredenburghi* SCHILDER, 1927 S¹ M⁶
 - pallida* (GRAY, 1828) P I S⁸ M²⁸
 - (c) *insulicola* SCHILDER & SCHILDER, 1938 M⁶
 - stohleri* CATE & SCHILDER, 1968 M³
 - subviridis* (REEVE, 1835) Q F⁷
 - (p) *dorsalis* SCHILDER & SCHILDER, 1938 D
 - (i) *pscatorum* SCHILDER, 1965 J
 - onyx* (LINNAEUS, 1758) N⁹ M J G⁸
 - (p) *adusta* (LAMARCK, 1810) A L²⁸³ P I S⁹
 - (i) *melanesiae* SCHILDER & SCHILDER, 1937 F¹ N⁴¹
- (m) *nymphae* (JAY, 1850) L⁴
 - ovum* (GMELIN, 1791) S D Q² N M J⁶
 - errones* (LINNAEUS, 1758) (A?) || I S D Q F N M J G T⁷
 - (m) *azurea* SCHILDER, 1968 D¹
 - cylindrica* (BORN, 1778) S Q F⁸ N M J G
 - (s) *sowerbyana* SCHILDER, 1932 D
 - caurica* (LINNAEUS, 1758) C A L E P I S D Q F N M J G T⁷
 - felina* (GMELIN, 1791) C A L⁷
 - (c) *fabula* (KIENER, 1843) E⁶ P
 - (p) *listeri* (GRAY, 1824) L^{not 7} I S D F N M J G T⁷
 - (c) *velesia* (IREDALE, 1939) V³ Q
- 632 *Notadusta* SCHILDER, 1935
- punctata* (LINNAEUS, 1771) A¹ L S D Q F N M J G T
 - rabaulensis* SCHILDER, 1964 N¹
 - katsuae* (KURODA, 1960) M² J
 - hartsmithi* SCHILDER, 1967 Q⁵
 - martini* (SCHEPMAN, 1907) Q² M⁴³
 - (p) *superstes* (SCHILDER, 1930) F²³

633 *Palmadusta* IREDALE, 1930*asellus* (LINNAEUS, 1758)A' L I⁸ S D Q F N M J G T⁸*clandestina* (LINNAEUS, 1767)C' A L E' I S D Q F N M J G T⁷³*artuffeli* (JOUSSEAU, 1876)J G⁸*saulae* (GASKOIN, 1843)S⁸ || D Q M³ J G⁸*contaminata* (SOWERBY, 1832)C' L || S⁸ D Q F⁸ N M J⁶*lutea* (GMELIN, 1791) (I⁶) S D N⁹ M J G⁸-(p) *humphreysii* (GRAY, 1825) Q F N⁴ G⁴*ziczac* (LINNAEUS, 1758)C A L E P I S D Q F N M J G⁸ T³*diluculum* (REEVE, 1845)C' A E⁴-(c) *virginalis* SCHILDER & SCHILDER, 1938 L*lentiginosa* (GRAY, 1825)E⁶ P I*gracilis* (GASKOIN, 1849)I⁶ S F' N M G⁸-(c) *japonica* (SCHILDER, 1931)

J

-(c) *macula* (ANGAS, 1867)

Q

-(s) *irescens* (SOWERBY, 1870)

D

-(p) *notata* (GILL, 1858)

A' E P

hammondae (IREDALE, 1939)Q N⁴-(i) *dampierensis* (SCHILDER & CERNOHORSKY, 1965)

D

-(p) *raysummersi* (SCHILDER, 1960)M⁷³*fimbriata* (GMELIN, 1791)C A L I⁶ S D F N M J G-(c) *unifasciata* (MIGHELS, 1845)

T H

minoridens (MELVILL, 1901)S⁸ || Q F N M³ J G T-(p) *serrulifera* SCHILDER & SCHILDER, 1938 T*microdon* (GRAY, 1828)S⁸ Q F N M J-(s) *chrysalis* (KIENER, 1843)A' L⁶ E⁴634 *Bistolida* COSSMANN, 1920*quadrinaculata* (GRAY, 1824)S D Q⁸ F N M J⁶ G*coxeni* (COX, 1873)F⁹ N⁴-(s) *hesperina* (SCHILDER & SUMMERS, 1963)N^{not 4} M³*interrupta* (GRAY, 1824)I S M⁶*palidula* (GASKOIN, 1849)M C⁸-(c) *luchuana* (KURODA, 1960)

J

-(i) *rhinoceros* (SOUBEVIE, 1865)

D Q F N

-(c) *summersi* (SCHILDER, 1958)F⁴*rashleighana* (MELVILL, 1888)F⁶-(s) *latior* (MELVILL, 1888)

H

teres (GMELIN, 1791)C A L I⁶ S D Q F N M J G T H-(p) *subteres* (WEINKAUFF, 1881)T⁶*goodallii* (SOWERBY, 1832)F³ G⁴ T*kieneri* (HIDALGO, 1906)A L I⁶-(c) *depriesteri* (SCHILDER, 1933)S D Q F N M J G⁸-(i) *landeri* (SCHILDER & GRIFFITHS, 1962) T⁸*owenii* (SOWERBY, 1837)

L

-(s) *vasta* (SCHILDER & SCHILDER, 1938) C A*hirundo* (LINNAEUS, 1758)A' L E I S D Q F N M J G T⁸*ursellus* (GMELIN, 1791)S D Q F N M J G⁸*erythraeensis* (SOWERBY, 1837)

E

stolida (LINNAEUS, 1758)C' A L I⁶ S D Q F N M J G T⁸635 *Ovatipsa* IREDALE, 1931*chinensis* (GMELIN, 1791)S⁸ D Q F N M³ J G T⁸ H-(i) *variolaria* (LAMARCK, 1810) C A L E-(m) *tortirostris* (SOWERBY, 1906) C-(p) *coloba* (MELVILL, 1888)E⁴ P⁴ I S⁹636 *Cribrarula* STRAND, 1929*cribraria* (LINNAEUS, 1758)I^{not 7} E⁴ I⁶ S D V⁶ Q F N M J G T⁸-(c) *comma* (PERRY, 1811)C' A L⁷*cribellum* (GASKOIN, 1849)A' L³*esotropia* (DUCLOS, 1833)L³*catholicorum* (SCHILDER & SCHILDER, 1938)Q² F⁸ N⁴*gaskoini* (REEVE, 1846)

H

-(p) *fischeri* VAYSSIÈRE, 1910F (T⁴?)*cumingii* (SOWERBY, 1832)G⁴ T

7

Erosariinae SCHILDER, 1924

71

(Pustulariini) SCHILDER, 1932

711 *Pustularia* SWAINSON, 1840*mariae* SCHILDER, 1927 Q⁸ F N M³ J⁶ G T H*globulus* (LINNAEUS, 1758)I⁶ S D Q⁸ F N M J G-(i) *brevirostris* SCHILDER & SCHILDER, 1938

A' L

mauiensis (BURGESS, 1967)

H

cicerula (LINNAEUS, 1758)A' L E⁴ || S D Q F N M J G⁸ T⁸-(c) *margarita* (DILLWYN, 1817)F N M³ G T*bistrinotata* SCHILDER & SCHILDER, 1937S D Q⁸ F N M J G T H*childreni* (GRAY, 1825)F N M³ J G T H-(i) *lemurica* SCHILDER & SCHILDER, 1938L³ (S²?)714 *Propustularia* SCHILDER, 1927□ *surinamensis* (PERRY, 1811)F⁶ A B⁷

- 72 (Erosariini) SCHILDER, 1924
- 721 *Monetaria* TROSCHER, 1863
moneta (LINNAEUS, 1758)
 C A L E P⁶ I S D Q F N M J G T H
annulus (LINNAEUS, 1758)
 C A L E P⁶ I S D Q F N M J G T
 - (c) *obelata* (LAMARCK, 1810) T²
- 722 *Naria* BRODERIP, 1837
irrorata (GRAY, 1828) F² N² M³ G T
- 723 *Erosaria* TROSCHER, 1863
dillwyni (SCHILDER, 1922) F⁴ (G?) T
beckii (GASKOIN, 1836) Q² N M⁴ J G T² H
macandrewi (SOWERBY, 1870) E P⁶
labrolineata (GASKOIN, 1849)
 S² D Q F N M J G H
 - (m?) *ogasawarensis* SCHILDER, 1944 G²
cernica (SOWERBY, 1870) L²⁴
 - (s) *viridicolor* (CATE, 1962) D
 - (p) *tomlini* SCHILDER, 1930 Z²¹ Q F⁷⁵ (T?)
 - (s) *maturata* (KIRA, 1959) J G²
 - (i) *marielae* (CATE, 1960) H
citrina (GRAY, 1825) C A⁶ (L?)
gangranosa (DILLWYN, 1817) L² E⁶ I S M⁶
boivini (KIENER, 1843) S² M
ostergaardi (DALL, 1921) H
helvola (LINNAEUS, 1758)
 A L E I S D V⁸ Q F N M J G T H
 - (c) *meridionalis* SCHILDER & SCHILDER, 1938 C
caputserpenti (LINNAEUS, 1758)
 C A L E⁴ I S D Z²³ Q² F N M J G T
 - (c) *kenyonae* SCHILDER & SCHILDER, 1938 D² V⁸
 - (c) *caputanguis* (PHILIPPI, 1849) Q⁶
 - (i) *caputophidii* SCHILDER, 1927 H
caputdraconis (MELVILL, 1888) R
☐ *albuginosa* (GRAY, 1825) C⁴ P⁸ E
☐ *spurca* (LINNAEUS, 1758) M L S G
☐ - (i) *sanctaelenae* SCHILDER, 1930 H
☐ - (p) *acicularis* (GMELIN, 1791) F A B
poraria (LINNAEUS, 1758) A¹ L¹⁶ S D
 - (i) *scarabaeus* (BORY, 1827)
 Z² Q F N M² J G T H
englerti (SUMMERS & BURGESS, 1965) R
erosa (LINNAEUS, 1758)
 C A L I S D Z³ Q F N M J G T H
 - (c) *pulchella* COEN, 1949 Q⁶
 - (p) *nebrites* (MELVILL, 1888) A² E P I⁹
ocellata (LINNAEUS, 1758) L³ P I || S²
- marginalis* (DILLWYN, 1827) C A L² E⁴ P⁶
miliaris (GMELIN, 1791)
 (A?) || S² D Q N³⁰ M J G⁸
 - (p) *eburnea* (BARNES, 1824) Q F N
lamarckii (GRAY, 1825) C A L⁷
 - (s) *redimita* (MELVILL, 1888) L^{not 7} P¹ I S⁸
turdus (LAMARCK, 1810) A² E P
 - (c) *pardalina* (DUNKER, 1852) E²
 - (c) *winckworthi* SCHILDER & SCHILDER, 1938 P⁴
guttata (GMELIN, 1791) F² N M³ J G⁸
- 724 *Staphylaea* JOUSSEAUME, 1884
limacina (LAMARCK, 1810)
 S² D V⁸ Q F N M J G⁸
 - (i) *interincta* (WOOD, 1828) C² A L I⁶
 - (p) *semitota* (MIGHELS, 1845) H
staphylaea (LINNAEUS, 1758)
 C A L I⁶ S D Q F N M J G T H
- 725 *Nucleolaria* OYAMA, 1959
nucleus (LINNAEUS, 1758)
 A L E I⁶ S D Q F N M J G T H
granulata (PEASE, 1862) H
 - (s) *cassiaui* (BURGESS, 1965) T²

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Seasonal Observations on Diet, and Stored Glycogen and Lipids in the Horse Clam, *Tresus capax* (GOULD, 1850)

BY

ROBERT G. B. REID

Department of Biology, University of Victoria, Victoria, British Columbia, Canada

(Plate 57; 1 Text figure)

INTRODUCTION

A STUDY OF TWO BIVALVES, *Lima hians* (GMELIN, 1791) and *Mya arenaria* LINNAEUS, 1758 revealed the presence of fat globules in the digestive diverticula of these animals (REID, 1966). Although glycogen is generally regarded as the major food storage compound in the Bivalvia, the fat contained in the digestive diverticula represents a significant amount of food energy. It was of interest therefore to undertake a seasonal study of the diverticular lipid as it related to lipid and glycogen storage in the gonad, which is the major organ of food storage, in the hope that the following questions might be answered: does the lipid of the digestive diverticula increase with an increase in food, or is it kept constant by the transport of excess lipid to the gonad? Does the diverticular fat represent a final energy store, to be depleted when the gonad glycogen and lipid are exhausted, or does the level of diverticular fat fall along with the level of glycogen and fat in the gonad? The seasonal availability of food was relevant to these problems and a study of the diet was undertaken along with stored food observations.

MATERIALS AND METHODS

Specimens of *Tresus* (= *Schizothaerus*) *capax* (GOULD, 1850) were dug at Esquimalt Lagoon, near Victoria, B. C. The average age of the animals was 4 years. They were collected at each spring tide over the period of a year, from July 1966 to June 1967. Adverse tidal and weather conditions made it occasionally impossible to collect, and sometimes limited the number of animals collected to two. The maximum number of animals sampled at any col-

lection time was 6, though the general condition of the gonads of all the animals dug was observed.

Bearing in mind the admonition of MANSOUR (1946) that digestion of some of the diet components in bivalves may be so rapid that any delay between collecting and examination of the stomach contents might give a wrong impression about diet, the stomach contents during the first few collections were examined on the beach, minutes after the animals were dug. It soon became obvious that a delay of many hours made little difference to the qualitative aspects of the stomach contents, and subsequent observations were made in the comfort of the laboratory. The stomach contents of animals which were dug while still covered with several feet of water during the ebb of the tide were also examined to compare actively feeding animals with those which had been exposed to the air for some hours. Within 12 hours of collection of the animals plankton samples were taken in the vicinity of the *Tresus* bed to determine the degree of selection exercised by the animals.

Lipid from the digestive diverticula and gonad was estimated by the chloroform/methanol extraction method of FOLCH *et al.* (1957). Glycogen was estimated by the anthrone method of VILES & SILVERMAN (1949) after extraction with 5% trichloroacetic acid at 90° C.

The digestive diverticula were usually invested with gonad tissue and it was difficult to separate the two tissues completely. This problem was surmounted thus: a previous histochemical study (REID, 1968) indicated that glycogen is absent from the digestive diverticula proper. Thus the glycogen value obtained from the diverticula must have come from investing gonad. Therefore, applying the glycogen:lipid ratio obtained from the gonad proper, the % dry weight of lipid derived from investing gonad

could be subtracted from the diverticular lipid value to obtain the true lipid value.

It should be observed here that the histochemical observation on *Tresus* diverticular fat included in the author's 1968 paper was false, due to a technical mishap, but that the observations on the other species were valid.

RESULTS

Stored Lipid and Glycogen

The results presented in Table 1 are graphed in Text figure 1, with different scales for average % dry weight lipid (left hand ordinate) and average % dry weight glycogen (right hand ordinate). Proceeding chronologically

Table 1

Percent dry weight of gonad lipid, diverticular lipid, and gonad glycogen of *Tresus capax*, averaged for all individuals collected.

[* = sample lost through technical error]

Date	Gonad Lipid	Diverticular Lipid (corrected value)	Gonad Glycogen
July 19	13.0	11.7	83.0
August 15	11.3	13.3	77.3
September 12	15.5	12.5	63.9
October 5	*	*	63.9
November 16	14.0	9.5	52.4
December 1	15.7	9.0	44.2
December 15	18.0	10.2	33.2
December 28	13.3	10.2	3.2
January 9	13.7	10.6	3.4
January 24	11.8	8.8	10.4
February 7	14.2	8.3	19.5
February 22	13.3	10.6	19.8
March 6	8.1	10.0	2.8
March 23	8.7	6.5	6.8
April 13	12.8	7.2	1.1
April 27	9.9	12.1	18.8
May 10	10.4	11.7	16.6
May 24	8.88	10.6	20.6
June 10	12.7	9.9	9.3
June 24	11.5	11.7	60.1

a falling off in glycogen begins about the end of July, 1966, the curve steepens in December and rapidly falls to a minimum value at the beginning of January. Rising temporarily during February it falls to a new low which lasts throughout March and part of April. Then the glycogen content begins to rise, interrupted by a slight

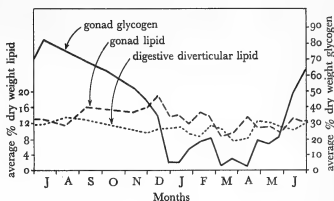


Figure 1

Graph of average % dry weight of gonad glycogen and lipid, and digestive diverticular lipid, in *Tresus capax*, over the period July 1966 to June 1967

dip in the beginning of May, to rise finally to the peak in July.

Both digestive diverticular and gonadal lipid are fairly similar in their progress. However, during November there is a slight rise in gonad lipid to reach the highest peak of the year, while the digestive diverticular lipid falls slightly. Both organs reach a low in lipid content which coincides with the second low in glycogen content, recovering in step with the glycogen halfway through April. In May the gonad lipid drops along with the glycogen, but the lipid in the digestive diverticula shows less of a dip at the same time.

Incidental observations on the general condition of the gonads of all the animals collected are included in Table 2, along with the diet observations. From these observations it seems that individual animals vary considerably during the period December to March in the amount of stored material (i. e., in degree of fatness). Since an average of 4 animals only was sampled at each collecting time over the year it looks as if this number of animals is too small to make the individual differences insignificant, and so the first low and the small peak in glycogen content during February is probably not indicative of the general trend throughout the population. Thus it is likely that a larger sample would have the glycogen content of the gonad falling smoothly from July to March.

Diet

Observations on diet and available phytoplankton are detailed in Table 2. Typical summer and winter stomach contents are shown in Plate 57. Naked flagellates are almost impossible to identify after exposure to the gastric juice of the clam, since they immediately become distorted and the flagellae are no longer obvious. Wherever

Table 2

Comparison of stomach contents of *Tresus capax* with available phytoplankton in the sea; notes on the general condition of the gonads of all animals collected

Date	Stomach Contents	Phytoplankton not in Stomachs	Ratio of fat: thin: depleted gonads
June 20	Many <i>Fragilaria</i> ; colonial <i>Navicula</i> ; various diatoms; detritus	0	4 : 2 : 0
June 30	Mainly <i>Fragilaria</i> ; detritus	0	7 : 2 : 0
July 18	Mainly <i>Melosira</i>	0	6 : 0 : 0
August 15	Various diatoms and flagellates	0	4 : 0 : 0
August 27	<i>Melosira</i> ; <i>Meridion</i> ; many flagellates	peridinians	5 : 0 : 0
September 1	Various diatoms	0	6 : 0 : 0
September 12	<i>Meridion</i> ; <i>Gomphonema</i> ; <i>Melosira</i> ; many flagellates	peridinians	4 : 0 : 0
October 5	<i>Meridion</i> ; <i>Gomphonema</i> ; <i>Melosira</i> ; many flagellates	<i>Coscinodiscus</i>	7 : 0 : 0
November 2	Various diatoms; flagellates	<i>Coscinodiscus</i>	5 : 2 : 0
November 16	A few, varied diatoms	0	2 : 2 : 0
December 5	A few <i>Melosira</i> ; flagellates	<i>Gyrosigma</i> ; <i>Triceratium</i> ; <i>Isthmia</i> ; <i>Chaetoceras</i> ; <i>Coscinodiscus</i>	1 : 3 : 0
December 15	Mainly detritus	As December 5	0 : 2 : 4
December 28	Mainly detritus; a few varied diatoms; flagellates	As December 5	0 : 2 : 5
January 8	Mainly detritus; a few varied diatoms; flagellates	peridinians; <i>Coscinodiscus</i>	0 : 1 : 5
January 24	Mainly detritus; a few varied diatoms; flagellates	<i>Biddulphia arctica</i>	0 : 2 : 4
February 7	Mainly detritus; a few varied diatoms; flagellates	<i>Biddulphia arctica</i>	0 : 3 : 1
February 22	Mainly detritus; a few varied diatoms; flagellates	0	0 : 1 : 1
March 6	Many <i>Biddulphia aurita</i>	0	0 : 0 : 2
March 22	Various diatoms	<i>Chaetoceras</i>	0 : 1 : 1
April 15	Many varied diatoms	0	0 : 1 : 3
April 27	Many small diatoms	0	0 : 3 : 1
May 10	Many <i>Fragilaria</i> ; <i>Melosira</i>	0	0 : 2 : 0
May 24	Many <i>Fragilaria</i> ; <i>Melosira</i>	0	0 : 2 : 0
June 10	Many <i>Fragilaria</i> ; <i>Melosira</i>	0	1 : 2 : 0
June 24	Many, varied diatoms	0	2 : 2 : 0

possible diatoms are identified to genus and occasionally to species.

In summary, there are a number of larger diatoms (with large cell bodies, or made effectively large by possessing many long spines) such as *Coscinodiscus*, *Chaetoceras*, and *Isthmia* species, and *Biddulphia arctica* (BRIGHTWELL, 1853) which commonly occur in the region of the clam beds, but which the animals do not ingest, presumably because of their large size, being selected out and rejected by the sorting mechanisms of the mantle cavity. At times there are also large peridinin dinoflagellates which are available to the clams, and which would seem to be within the upper limits of the accept-

able particle size (150μ), but which are not ingested, for reasons unknown. For the most part *Tresus* ingests all of the other smaller phytoplankton members, any bloom of a particular species being reflected by the stomach contents. Some time in November the amount of the food in the stomachs was noticeably reduced from the earlier part of the year, and from December to the end of February most of the particulate material in the stomach was inorganic or detrital. As early as March 6 the first phytoplankton bloom, of *Biddulphia aurita* (LYNGBYE, 1819) appeared, and the quantity of phytoplankton found in the stomachs gradually increased into June where it seemed to level off.

Explanation of Plate 57

Figure 1: Stomach contents of *Tresus capax*, collected July 1966; various diatom species; flagellates

Figure 2: Stomach contents of *Tresus capax*, collected December 1966; several flagellates; diatom frustules; *Cristihipira*

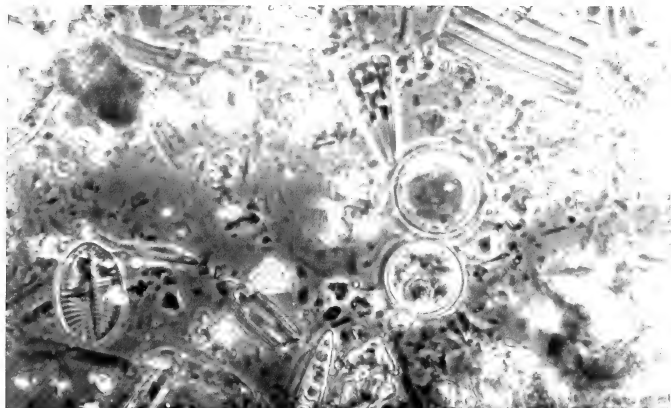


Figure 1

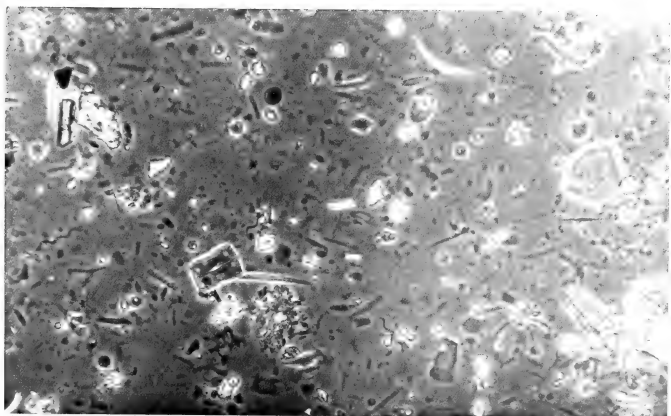


Figure 2



The stomachs of all the animals examined contained a species of the spirochaete genus *Cristispira*. These bacteria were most abundant during the summer. Currently work is underway to determine the role of the spirochaetes in the alimentation of *Tresus*.

DISCUSSION

When this work began the unwarranted assumption was made that adequate information would be available on the biology of *Tresus*. Unfortunately, most of the work on *Tresus* has been ecological, and the only relevant work is that of SWAN & FINUCANE (1953) in which the authors imply that *Tresus capax* is a winter-spawning species. Dr. Quayle of the Biological Station, Nanaimo, in a personal communication informs me that the condition of the spat also indicates that *T. capax* is a winter-spawner. My lipid and glycogen analysis, together with the observations of gonad condition are only explicable in terms of *T. capax* being an early spawner, but it would have been more satisfactory to have done a seasonal histological study of the gonads along with the other aspects of the work.

The preliminary questions which this work set out to answer are satisfied, with respect to this species. The amount of fat in the digestive diverticula is relatively constant, falling from a summer level of around 13% dry weight to a winter low of about 8%. Thus fat stored in the digestive diverticula of *Tresus* can be regarded mainly as an energy store which is called upon only after several months of food scarcity, during which time the glycogen store of the gonad is rapidly being depleted. How dynamic is the flow of lipid in and out of the storage globules is not known, and the transport mechanism responsible for moving excess fat from the tubule cells of the digestive diverticula is equally unclear, though amoebocytes may have a role in this transport as suggested by YONGE (1926).

The lipid in the gonad fluctuates rather more. Of particular interest is the peak in mid-December which probably is related to the build-up of lipid in the formation of eggs in the gonad. In a study of *Crassostrea gigas* (THUNBERG, 1793) by MASUMOTO *et al.* (1934), reported in a review of the subject by GODDARD & MARTIN (1966), a similar lipid peak was observed during the period of "gonadal ripening." This accumulation of gonad lipid probably occurs at the expense of both gonadal glycogen and diverticular lipid. The drop in gonadal lipid after mid-December is explicable as the release of eggs and the continued use of fat as an energy source. This peak cannot be easily dismissed as an artifact caused by

the smallness of the samples, since the gonadal glycogen of the animals sampled is rapidly decreasing.

The sudden drop in the level of glycogen occurs partly because food becomes noticeably scarce in November, and the glycogen is the major storage product. As well as the depletion of glycogen for the purpose of fueling the general metabolism of the animal, extra demands are being made upon this food store for the production of eggs and sperm. The re-accumulation of glycogen lags about one month behind the re-availability of phytoplankton; the lag presumably reflects the increased energy requirements of the animals for growth. After the middle of April the food available to the clams is in excess of all the energy requirements, and storage can rapidly take place.

ACKNOWLEDGMENTS

I am grateful to Miss Margaret Campbell who did most of the analytical work. This study was supported by a grant of the National Research Council of Canada.

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Seasonal Gonadal Changes in Two Bivalve Mollusks in Tomales Bay, California

BY

VERNON KENNETH LEONARD, Jr.

Pacific Marine Station, Dillon Beach, California 94925

(Plates 58 to 60; 4 Text figures; 1 Map)

INTRODUCTION

Pododesmus cepio (GRAY, 1850), A BIVALVE mollusk of the family Anomiidae, is native to the Pacific coast of North America and common in Tomales Bay, California. A small population of the European oyster, *Ostrea edulis* LINNAEUS, 1758, is being raised experimentally at the Tomales Bay Oyster Company. The histological study of the seasonal gonadal changes of these two species, in Tomales Bay, is described below.

The study of gametogenesis in *Ostrea edulis* in Tomales Bay is desired to evaluate the reproductive adaptation of this species to a new set of ecological conditions. The inclusion of the native *Pododesmus cepio* in this study allows comparison of the gonadal development of these two species. Such a comparison aids not only in understanding the seasonal gonadal changes in both species, but also in examining the adjustment of the introduced form, *O. edulis*, to a new environment.

At the present time the oyster industry in Tomales Bay imports large numbers of oysters bred in other localities and raises them until they reach marketable size. These imported oysters, the Japanese [*Crassostrea gigas* (THUNBERG, 1793)] and the American oyster [*C. virginica* (GMELIN, 1791)], do not normally reproduce in California waters. The oyster industry in California would be revolutionized if an exotic oyster, such as *Ostrea edulis*, were able to grow and reproduce in these waters.

Knowledge of the reproductive cycle in *Pododesmus cepio* is valuable not only because it offers a natural comparison to the introduced species, *Ostrea edulis*, but also because it would then be the first member of the family Anomiidae whose natural seasonal gonadal changes have been examined.

There are no references to gonadal studies of *Pododesmus cepio*. However, prior to 1953 (FITCH, 1953) *P. cepio* was considered to be the same species as a very closely related form, *P. macroschisma* (DESHAYES, 1839). All available literature deals with this northern species. KELLOGG (1915) described the gross morphology and ciliary currents of the mantle cavity of *Monia* (= *Pododesmus*) *macroschisma*. FRIZZELL (1930) published a note on the collection of a specimen of *P. macroschisma* in a *Teredo navalis* (LINNAEUS, 1758) burrow from Puget Sound. Brief references were also made to *P. macroschisma* in discussions of the family Anomiidae by ATKINS (1937) and YONGE (1962). There are no works on the seasonal gonadal changes in any other member of the Anomiidae.

In contrast, *Ostrea edulis* is one of the most thoroughly studied of all mollusks. ORTON (1920, 1927, 1933, 1937), COLE (1936, 1941, 1942), and KORRINGA (1940, 1952, 1957) have studied many aspects of the reproductive cycle and sex change of the European oyster in its native waters. LOOSANOFF (1955) introduced *O. edulis* to New England waters in 1949 and later studied the seasonal gonadal changes of these oysters while they were adjust-

Explanation of Plate 58

Figure 1: Section of gonad of undifferentiated male *Pododesmus cepio*. Collected October 1966 $\times 125$

Figure 2: Section of gonad of undifferentiated female *Pododesmus cepio*. Collected October 1966 $\times 125$

Figure 3: Section of gonad of undifferentiated *Ostrea edulis*. Collected November 1966 $\times 125$

Figure 4: Section of gonad of developing male *Pododesmus cepio*. Collected February 1967 $\times 500$

Figure 5: Section of gonad of developing female *Pododesmus cepio*. Collected January 1967 $\times 125$

Figure 6: Section of gonad of developing *Ostrea edulis*. Collected December 1966 $\times 125$

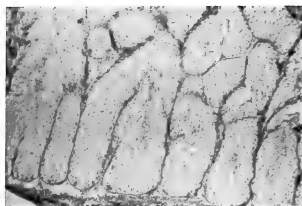


Figure 1

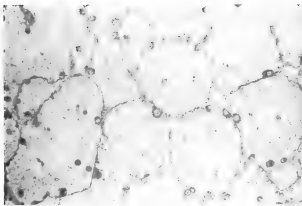


Figure 2

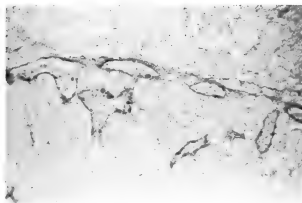


Figure 3

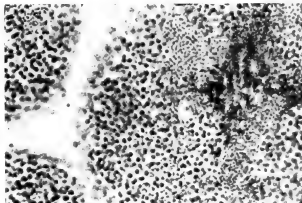


Figure 4

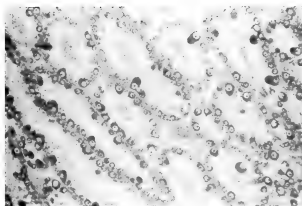


Figure 5

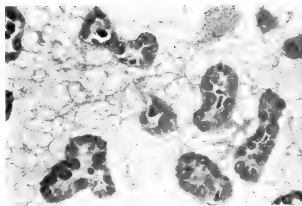


Figure 6



ing to the new environmental conditions (LOOSANOFF, 1962).

Three hundred European oysters were raised from larvae cultured in the U. S. Bureau of Commercial Fisheries Laboratory at Milford, Connecticut. With the assistance of Dr. Victor L. Loosanoff and the courtesy of the State of California, these oysters were imported to Tomales Bay in October 1965.

ACKNOWLEDGMENTS

I wish to thank Drs. Victor L. Loosanoff and Edmund H. Smith for their kind assistance and encouragement during this study. I also thank Mr. Carl Berg and Mr. Les Watling for aid in collecting the specimens.

METHODS AND MATERIALS

Sampling Methods

About 25 specimens of *Pododesmus cepio* were taken monthly from a natural population in White Gulch, a small cove in Tomales Bay, California (see Map, Text figure 1). Samples were collected from October 1966 to March 1968. With each collection, water temperature, salinity, and turbidity measurements were taken.

Samples of *Ostrea edulis* were collected twice a month at the beginning of the study and during the most active reproductive period (March to July), then once a month for the duration of the study. The sampling program extended from October 1966 to December 1967. As with the White Gulch samples, temperature, salinity, and turbidity were measured at each collection.

During the late spring and summer months, attempts were made to obtain larvae from the spawning oysters. To collect settling larvae, strings of cleaned oyster shells were suspended in the water around the racks in which the oysters were kept.

Laboratory Procedure

Each specimen was measured and the gonad examined externally for features, such as size and color, which might indicate its stage of development. The gonadal tissue was prepared for histological study as follows: transverse sections of the gonad, 1 to 2 mm thick, were fixed in Bouin's fluid, dehydrated in isopropyl alcohol and embedded in paraffin (melting point 52.5°C). Sections, 8 μ thick, were stained with Heidenhain's iron hematoxylin and counterstained with eosin.

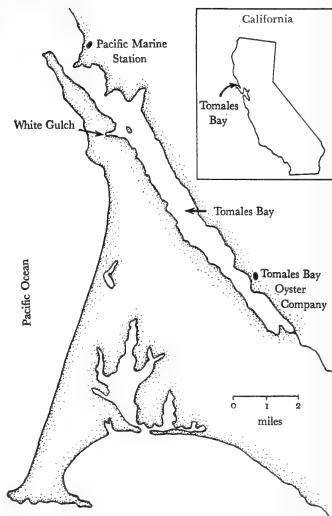


Figure 1
Map of the Study Area

CRITERIA FOR ESTABLISHING STAGES OF DEVELOPMENT

After examination of the gonadal tissue, a number from 1 to 5, representing a particular stage of development, was given to each specimen. Each of these stages represented a naturally occurring and characteristic change in the gonads of the animals during the entire reproductive cycle.

Stage I

This stage represents the resting or indifferent phase through which *Ostrea edulis* and *Pododesmus cepio* pass

following the activity of the previous reproductive period (Plate 58, Figures 1, 2, and 3). In *O. edulis*, the gonadal tissue surrounding the digestive gland is reduced to a thin, translucent layer less than 1 mm thick. The fine tubules connecting the follicles to the genital ducts can be seen through this layer. In *P. cepio*, the gonad forms a layer of tissue partially covering the stomach and continues anteriorly as an irregular tube attached to the byssus gland. During this period the gonad is clear, and the delicate genital tubules can be seen beneath the surface epithelium. The gonad of *P. cepio* is usually 2-3 mm thick at this time.

In both species the follicles are separated by connective tissue, often forming isolated pockets of follicular tissue. Usually the follicles are small and completely void of sex cells. However, primary germ cells are sometimes present and are attached to the follicular wall. The gonads of both species are colorless at this time; it is difficult to determine their sex.

Stage II

Early gametogenesis in *Ostrea edulis* and *Pododesmus cepio* is characterized by the development of primary and secondary oögonia, spermatogonia, and, in some advanced cases, oöcytes and spermatids (Plate 58, Figures 4, 5, and 6). The connective tissue surrounding the follicles supplies nutrient material (glycogen) for the developing cells (LOOSANOFF, 1942). As the sex cells proliferate, the follicles slowly enlarge and become more numerous. During early development all stages of gametogenesis can usually be found in one individual. *Ostrea edulis* often has male and female sex cells in various stages of gametogenesis in the same or adjacent follicles. In general, however, mature gametes are not present at this time.

Externally the gonads become opaque as the developing cells fill the follicles. At this time the gonad of the female *Pododesmus cepio* has a faint red-orange color which becomes more brilliant as the animal ripens. Throughout their development, the gonads of the male

have a creamy white color, similar to that of *Ostrea edulis*.

The later stages of gametogenesis are characterized by the rapid increase in numbers of mature eggs and sperm. In *Ostrea edulis*, ripe eggs interspersed with oöcytes line the follicles. In males and hermaphroditic individuals, the spermatids and spermatozoa fill the lumen of the follicle. In this species the sperm characteristically form spermballs with the tails projecting outwards as in Plate 59, Figure 9.

As the gonads of *Pododesmus cepio* ripen, eggs rapidly fill the follicle, with a corresponding decrease in the number of cells in earlier stages of oögenesis. Male follicles typically have primary stages of spermatogenesis in the outer portion of the follicle, with more mature sex cells occupying the lumen. In *P. cepio*, the sperm are arranged in branching networks with their tails aligned toward the center of the follicle.

Externally the gonads of both species become firmer and larger than during earlier stages. The color also becomes brighter, especially in female *Pododesmus cepio*.

Stage III

When fully ripe, both species possess large, characteristically swollen follicles containing mature gametes (Plate 59, Figures 7, 8, and 9). Developing stages of gametogenesis are seldom present at this time. Ripe ova and spermatozoa are commonly found in the genital ducts awaiting discharge. Mature eggs in *Pododesmus cepio* often have a highly compressed appearance. The eggs are 60 to 75 μ in size at this time. In *Ostrea edulis*, the eggs have a diameter of 85 to 90 μ but do not appear compressed.

At this time the gonad of *Pododesmus cepio* attains its largest size, sometimes a centimeter or more in diameter. *Ostrea edulis*, however, never develops a thick gonadal layer. In Tomales Bay, as in Boothbay Harbor, Maine (LOOSANOFF, 1962), the gonad of *O. edulis* is rarely more than 1 $\frac{1}{2}$ mm thick. The ripe condition in the European oyster is obvious when the gonad is punctured, allowing the tightly packed gametes to be released.

Explanation of Plate 59

Figure 7: Section of gonad of ripe male *Pododesmus cepio*.
Collected June 1967 $\times 125$

Figure 8: Section of gonad of ripe female *Pododesmus cepio*.
Collected June 1967 $\times 125$

Figure 9: Section of gonad of ripe *Ostrea edulis*.
Collected May 1967 $\times 125$

Figure 10: Section of gonad of spawned male *Pododesmus cepio*.
Collected August 1967 $\times 125$

Figure 11: Section of gonad of spawned female *Pododesmus cepio*. Collected August 1967 $\times 125$

Figure 12: Section of gonad of spawned *Ostrea edulis*.
Collected August 1967 $\times 125$

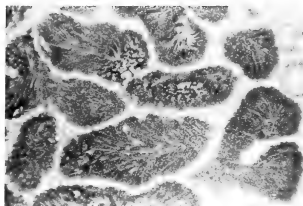


Figure 7

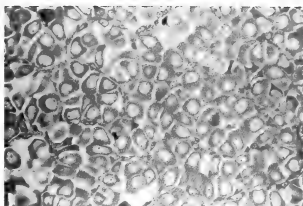


Figure 8

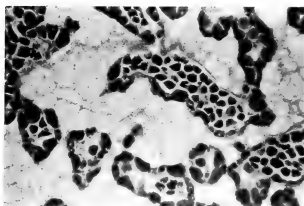


Figure 9

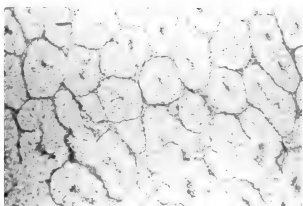


Figure 10

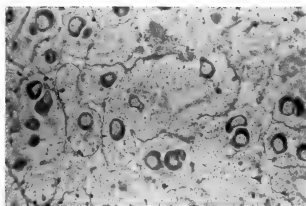


Figure 11

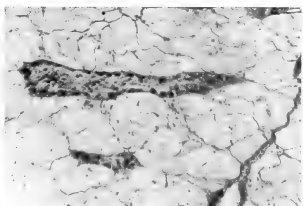


Figure 12



Stage IV

Examination of recently spawned specimens of *Pododesmus cepio* and *Ostrea edulis* reveals large empty follicles (Plate 59, Figures 10, 11, and 12). Although a few unspawned gametes are often visible in the lumina of the follicles, no developing cells are present. In many cases, partially spawned animals will have empty follicles on the periphery of the gonad but fully ripe follicles closer to the digestive gland. Specimens of *O. edulis* commonly have cells of the next sexual phase undergoing gametogenesis in the evacuated follicles immediately following spawning. For example, a female phase may be completed early in the summer with a male phase beginning soon after the spawning of the eggs.

The appearance of the gonads following spawning is dramatically different from the previous ripe condition. The gonads are greatly reduced in size, no longer firm, and usually void of sex cells in areas adjacent to the genital ducts. This shrunken condition is especially obvious in *Pododesmus cepio*.

Stage V

Ostrea edulis and *Pododesmus cepio* pass through a period of resorption following spawning, in which any remaining sex cells are absorbed by phagocytes (Plate 60, Figure 13). During this time the follicles of both species are small; the lumina are filled with phagocytes and fragments of partially resorbed gametes. Resorption is a slow process and often extends over several months' time, thereby overlapping with the development of new gametes.

GAMETOGENESIS

It is appropriate to begin the description of gametogenesis in *Pododesmus cepio* and *Ostrea edulis* with the inactive period (Stage I) following spawning and resorption. In Tomales Bay this period occurred during October and November, in both 1966 and 1967. The water temperature was 16° C over the *O. edulis* population and approximately 13° C in White Gulch (Text figures 2 and 3). The gonads of both species were typically in the Stage I condition, undifferentiated and empty. During this stage the oyster usually had some primary germ cells attached to the follicular wall, while *P. cepio* was completely barren. The duration of this indifferent period was similar for *P. cepio* and the oyster (Tables 1 and 2).

Early gametogenesis (Stage II) began late in November 1966 and continued until April and early May 1967.

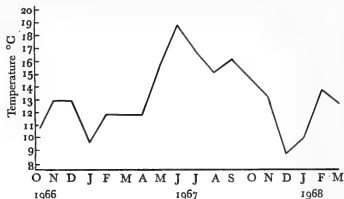


Figure 2

Water Temperature at White Gulch, Tomales Bay, California, from October 1966 to March 1968

Although the water temperature in both study areas dropped to 12.5° C, each species had begun to show gonadal differentiation by early December 1966. The European oyster developed more rapidly than did *Pododesmus cepio*. Ripe *Ostrea edulis* were found as early as December 1966, while a significant number of ripe *P. cepio* was not found until April 1967. All stages of spermatogenesis and oogenesis were found during this active period. In both species, individuals were found lagging behind or developing more rapidly than the rest of the specimens of the sample.

As the water warmed from a low of 9° C in January to 12–13° C in March 1967, both species continued to



Figure 3

Water Temperature at Tomales Bay Oyster Company, California, from October 1966 to January 1968

Table 1

Numbers of *Pododesmus cepio* in different stages of gonad development recorded at each collection; October 1966 to March 1968

Stage	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March
	1966										1967				1968			
I.	7		4	1	3	1					6	2	10	12	10			
II.	1	12	11	14	15	29	30	34	3	1	1		3	4	10	31	33	15
III.		3				1	4	1	15	8	1		4	10	3	3		
IV.									10	22	22		10	4				
V.	2								1	2	16	5	11	12	12	3	2	

Note: The approximate duration of each stage is indicated by the blocks surrounding the numbers in the table above.

Table 2

Numbers of *Ostrea edulis* in different stages of gonad development recorded at each collection; October 1966 to December 1967

Stage	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December
	1966										1967				
I.	10	9	1										4	8	5
II.	2	20	26	10	13	11	17	4	5					1	1
III.	1		1	3	2	3	11	12	17	14	1	2	4	5	2
IV.						1	1	4	8	3	6	3		1	
V.	1						1			1	1	4	1	1	1

Note: The approximate duration of each stage is indicated by the blocks surrounding the numbers in the table above.

Explanation of Plate 60

Figure 13: Section of gonad of resorbing female *Pododesmus cepio*. Collected November 1967 $\times 125$

Figure 14: Section of gonad of hermaphroditic *Pododesmus cepio*. Collected November 1967 $\times 125$

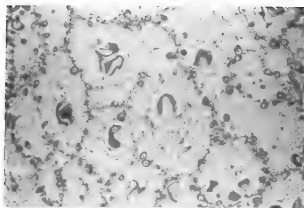


Figure 13

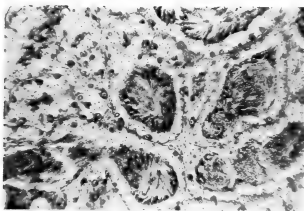


Figure 14



ripen, reaching advanced stages of gametogenesis in April.

The fully ripe condition (Stage III) was not prevalent in *Ostrea edulis* until April 1967, when 30% of the sample attained this stage. *Pododesmus cepio* did not become fully mature until late May or early June 1967, although ripe individuals were observed in late March. During April the water temperature in both localities rose above 15° C, after which the gonads of both species ripened rapidly.

The climax of the reproductive cycle of the two bivalves in Tomales Bay (Stage IV) was reached during July 1967 (Tables 1 and 2). The duration of the spawning period in *Ostrea edulis* was from May to September 1967, while in *Pododesmus cepio* it extended only from June to August. The period of most intense spawning coincided with the warmest water temperatures of the year, 19° C in White Gulch and 21.5° C at the oyster bed.

Following spawning, each species entered a period of resorption (Stage V) during September and October of 1966 and 1967. Phagocytic cells were found within the lumina of the follicles, resorbing unspawned material. In *Pododesmus cepio* the phagocytes invade the follicles from the surrounding connective tissue, while in *Ostrea edulis* the phagocytes enter directly from the blood vessels (LOOSANOFF, 1962). The resorptive phase provides some nutritive material for the development of new germ cells. Resorption is a slow process, both in Tomales Bay and in Boothbay Harbor, Maine (LOOSANOFF, 1962), and often overlaps the early stages of gametogenesis in the next season, thereby completing the reproductive cycle.

FACTORS AFFECTING GAMETOGENESIS

Temperature

Gametogenesis in *Ostrea edulis* and *Pododesmus cepio* is an uninterrupted process in Tomales Bay. Once begun in November, the development continued until the gonads were ripe in March or April.

This uninterrupted development is unusual for *Ostrea edulis*. ORTON (1933) stated that *O. edulis* in England began rapid gonadal development in the early spring following a period of hibernation (December to February). LOOSANOFF (1962), in discussing gonadal changes in *O. edulis* in Maine, noted that the oyster passed through a period of dormancy during the winter months and did not begin gametogenesis until April or May each year when the water temperature reached 10° C. In the Adriatic Sea, *O. edulis* began gametogenic activity in the early spring and usually spawned by April following the period of winter quiescence (PERUŠKO, 1967).

Interrupted gametogenesis is common in several other bivalves. *Crassostrea virginica* is dormant during the winter in Long Island Sound and exhibits rapid gonadal development in May and June when the water temperature rises from 10° C to 12° C (LOOSANOFF, 1942). In *Cyprina islandica*, the ocean quahog of Rhode Island, gametogenic activity is slowed appreciably, although not completely arrested during the cold winter months (LOOSANOFF, 1953). The hard shell clam, *Mercenaria mercenaria* (LINNAEUS, 1758), also passes through a winter period of reduced gametogenic activity in Long Island Sound (LOOSANOFF, 1937a).

It is not surprising that *Ostrea edulis* should develop well and spawn in Tomales Bay, for the temperature range is probably more favorable than in its native European waters. In Tomales Bay the water temperature dropped to approximately 9° C during December 1966 and January 1967, but rose above 15° C by April 1967 (Text figures 2 and 3). This "critical temperature" (ORTON, 1920) was maintained or exceeded from May to October 1967, allowing 7 months for active gonadal development and spawning. This favorable temperature range no doubt accounts for the early and rapid maturation of the gonad of *O. edulis* in Tomales Bay.

Many early workers, in studying lamellibranch reproduction, discussed the existence of a minimum temperature below which the bivalves could not successfully reproduce. HOPKINS (1936, 1937), in his work with *Ostrea lurida* CARPENTER, 1864, noted that ripening and spawning of the oyster in British Columbia did not occur until the water temperature reached 15 to 16° C. COE (1931b, 1932) found that when the water temperature reached 15° C in southern California, *O. lurida* would spawn soon after. More recently, LOOSANOFF & NOMEJKO (1951) showed that not only is there a minimum temperature limiting reproduction, but oysters raised in northern latitudes would spawn at different times and different temperatures than individuals raised in warmer, southern areas. They found that actual physiological races existed in the same species grown in different areas. Chesapeake Bay oysters would not spawn when transferred to the cold waters of Long Island Sound. *Crassostrea virginica* from Milford, Connecticut, however, would spawn earlier and at lower temperatures when transplanted in Chesapeake Bay (LOOSANOFF & NOMEJKO, 1951).

Although no conclusive evidence is available regarding *Pododesmus cepio* in Tomales Bay, the indication is that a temperature of 15° C or higher is necessary for the ripening and spawning of gametes. A recent study has been made of the seasonal gonadal changes in *Crassostrea virginica* and *C. gigas* in Tomales Bay (BERG, personal

communication). It was found that gametogenesis occurred in the spring, and that the gametes began to ripen in May and June after the water temperature reached 15° C. Likewise, *Ostrea edulis* began to ripen significantly when the water temperature rose above 15° C. This evidence suggests that, as with the Olympia oyster, *O. lurida*, 15° C may be the minimal temperature; below this temperature *P. cepio* and *O. edulis* cannot spawn in Tomales Bay.

Salinity

The oysters were grown in wire cages suspended 1 foot above the bottom where the winter salinity never dropped below 22.5‰. Although the surface salinities dropped below 5‰ at the oyster beds, and below 11‰ in White Gulch (Text figures 4 and 5), the development of the gonads appeared unaffected by the lowered concentrations. *Pododesmus cepio* occurs in the low intertidal zone, where the briefly lowered salinity (during February storms) could only be deleterious during extremely low

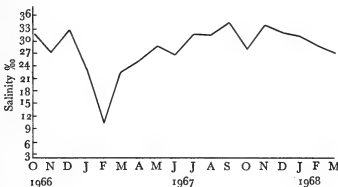


Figure 4

Salinity at White Gulch, Tomales Bay, California,
from October 1966 to March 1968

tides. According to DAVIS & ANSELL (1958), development and larval growth of *Ostrea edulis* was normal at salinities of 22.5‰ in Milford, Connecticut. Since the average salinity at the Tomales Bay oyster beds was 27 to 32‰ for most of the year, it is unlikely that extremes in salinity adversely affected gonadal development.

Hydrogen-Ion Concentration

The hydrogen-ion concentration in both areas was remarkably constant during the study period. The pH ranged from 7.6 to 8.2. CALABRESE & DAVIS (1966) found that oysters kept at a salinity of 27‰ could toler-

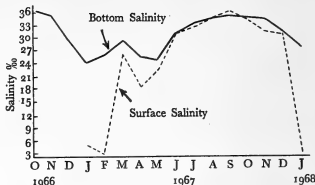


Figure 5

Salinity at Tomales Bay Oyster Company, California,
from October 1966 to January 1968

ate extremes in pH from 6.75 to 8.75. In most cases the oysters developed normal straight-hinge larvae. Since the observed pH in Tomales Bay was within the accepted tolerance limits, it is doubtful that this factor caused any changes in the gonadal development of *Ostrea edulis* and *Pododesmus cepio*.

Turbidity

Excessive turbidity most likely has a greater effect on both species, especially their larval forms, than lowered salinities. The author observed turbid water at Tomales Bay Oyster Company all year, with extreme conditions at times of peak run-off from winter and late spring storms. The White Gulch area was turbid only during and after heavy spring rains. In many cases during the summer spawning periods, the oyster shells would be covered with a layer of silt and mud several millimeters thick. Quantitative turbidity measurements made by Pacific Marine Station (Water Quality Study) substantiate these field observations. These data are available in the recent Federal Water Pollution Control Administration Progress Report (WP-GW-1061-02).

It seems likely that excessive turbidity did affect larval development of *Ostrea edulis* in Tomales Bay. Although the animals developed and spawned normally, no larvae were seen by this investigator. Every specimen sampled during the spring and summer months was examined for the presence of larvae in the gills, but none were found. Similarly, BERG (personal communication), in his study of *Crassostrea gigas* and *C. virginica*, found only 4 or 5 bivalve larvae and a similar number of spat during the summer spawning period.

In addition to the high concentration of mud and silt observed, a large bloom of dinoflagellates occurred during July and August at the oyster beds. These turbidity-causing organisms, together with particles of silt, affected the oyster larvae by covering all available surfaces with material, thus preventing any larvae present from settling. Moreover, the large concentrations of plant cells either removed nutrients from the water vital to the larvae, or released toxic metabolites causing mass mortality. Finally, CALABRESE & DAVIS (1966) noted that high turbidity could lower the pH, in some cases below the tolerance limit of the larvae, and cause mortality.

While turbidity and related factors most likely caused larval mortality, there was less than 10% mortality among the *Ostrea edulis* adults. It is doubtful, therefore, that turbidity affected gonadal changes in the European oyster. In comparison, no significant mortality of *Pododesmus cepio* larvae was observed; in fact, spat were found just a few weeks after the main spawning period in August.

Sexuality

Hermaphroditism in mollusks, especially in bivalves, is well known and has been thoroughly reviewed by COE (1943, 1944). ORTON (1927, 1933) established that *Ostrea edulis* is a protandric hermaphrodite which passes through consecutive sexual phases. Examination of *O. edulis* in Tomales Bay revealed that the majority of the animals developed as functional females early in spring and, immediately after spawning, began producing male gametes. COE (1931b, 1932) has described similar sexual phases in *O. lurida* and in the ship worm, *Teredo navalis* (LINNAEUS, 1758) (COE, 1941).

Approximately 1% of the *Pododesmus cepio* examined was hermaphroditic (Plate 60, Figure 14). In 4 of the cases the animal had spawned as a male and still had undischarged sperm in the tubules; at the same time young oocytes were developing on the follicular walls. In another case the animal had fully developed sperm and eggs.

Over 95% of all animals under 40 mm (average of length and width) were male. This evidence suggests that *Pododesmus cepio* is protandric. In addition, the sex ratio of larger animals (55% ♂, 40% ♀, 4% undetermined) indicates that some sex reversal must occur as the animal becomes older. As noted earlier, both *P. cepio* and *Ostrea edulis* pass through an indifferent stage in which the sex cannot be determined. It is possible that during this period *P. cepio* may change sex if the appropriate stimulus is present.

CONCLUSION

Seasonal gonadal changes in *Ostrea edulis* and *Pododesmus cepio* in Tomales Bay took place in a continuous manner. Gametogenesis began in the late fall and continued until the ripened condition was attained in the spring. *Ostrea edulis* began mass spawning in June, while *P. cepio* did not spawn until July and August. Resorption of unspawned gametes took place for varying lengths of time in each species following spawning. Prior to the onset of the next reproductive cycle, *P. cepio* and *O. edulis* underwent a brief period of quiescence, during which time the gonads were generally undifferentiated.

The temperature and salinity factors were favorable for the normal development and spawning of the imported European oyster. However, highly turbid conditions at the oyster beds appear to be responsible for the failure of *Ostrea edulis* to propagate in Tomales Bay.

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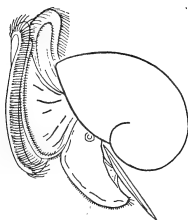
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The Shell Structure and Mineralogy of *Chama pellucida* BRODERIP

BY

JOHN DAVID TAYLOR

Department of Zoology, British Museum (Natural History), London

AND

WILLIAM JAMES KENNEDY

Department of Geology and Mineralogy, Oxford

(Plates 61 to 64; 6 Text figures)

THE CALCIFIED SHELL OF THE BIVALVIA is normally built up of two forms of calcium carbonate, aragonite and calcite. Shells may be wholly aragonitic, or may contain both aragonite and calcite, always in separate monomineralic and structurally distinct layers.

Amongst extant bivalves, calcite is confined to 7 superfamilies of the subclass Pteriomorpha (classification after NEWELL, 1965) and a single member of the Heterodonta. This species is *Chama pellucida* BRODERIP, 1835.

Primary calcite was also present in an extinct heterodont group, the rudists (Hippuritacea; KENNEDY & TAYLOR, 1968).

The distribution in living bivalves is:

	superfamilies	
Palaeotaxodonta:	Nuculacea	aragonite only
	Nuculanacea	aragonite only
Cryptodonta:	Solemyacea	aragonite only
Pteriomorpha:	Arcacea	aragonite only
	Limopsacea	aragonite only
	Mytilacea	aragonite only
		or aragonite + calcite
	Pinnacea	aragonite + calcite
	Pteriacea	aragonite + calcite
	Pectinacea	aragonite + calcite
	Anomiacea	aragonite + calcite
	Limacea	aragonite + calcite
	Ostreacea	aragonite + calcite
Palaeoheterodonta:	Unionacea	aragonite only
	Trigonacea	aragonite only
Heterodonta:	All	wholly aragonite, so far as is known, except for <i>Chama pellucida</i> .
Anomalodesmata:	All	wholly aragonitic

The single occurrence of calcite in *Chama pellucida*, outside the Pteriomorpha, is therefore of considerable interest. This fact was first reported by LOWENSTAM (1954a, 1954b) and confirmed subsequently by him (LOWENSTAM, 1963, 1964) and by our present work.

In bivalve superfamilies where calcite and aragonite occur together in the same shell, LOWENSTAM (1954a, 1954b, 1963, 1964) and DODD (1963, 1964) have shown that in some cases the proportion of aragonite is related to temperature. Species living in warmer water tend to have a higher proportion of aragonite in their shells than species living in temperate or cold waters.

Chama pellucida is a West American species ranging from Peru to California. It thus extends into cooler waters well outside the normal range of the Chamacea, which are otherwise more or less confined to the tropics and subtropics. LOWENSTAM (1954b, 1963, 1964) was thus able to use *Chama pellucida* to illustrate the temperature effect on mineralogy. That is, calcite appears in a species which inhabits cooler waters than the other wholly aragonitic members of the superfamily. Furthermore, he illustrated (LOWENSTAM, 1963, plate iv) the microstructure of the shell, stating that the outer aragonitic layer of the shell in warm water species of *Chama* is transformed to an outer calcitic layer in *Chama pellucida*. This layer has a distinct and different microstructure.

During a general survey of the mineralogy and microstructure of the Bivalvia (TAYLOR, KENNEDY & HALL, in press), we have found this interpretation to be incorrect. In view of the exceptional nature of *Chama pellucida* we present this more detailed study.

METHODS

Mineralogical determinations were carried out by X-ray diffraction on samples of the shell layers of 29 species of

Chamaea. The microstructure of the shell was examined at optical level by use of acetate peels prepared from polished, etched sections (methods after KUMMEL & RAUP, 1965). Petrographic thin sections were also examined. Fine structure was studied on shell interiors and on polished and E.D.T.A. etched sections with a Cambridge Instrument Company (U. K.) 'Stereoscan' scanning electron microscope. Two-stage formvar, gold palladium shaded replicas were studied by transmission electron microscopy (techniques from KAYE, 1964).

OBSERVATIONS

The shell of most *Chamaea* consists of two layers, an outer, crossed-lamellar layer and an inner, complex crossed-lamellar layer (terminology from BOGGILD, 1930, TAYLOR, KENNEDY & HALL, in press). These two layers are separated by a thin layer of a blocky prismatic aragonite. This is the pallial myostracum (OBERLING, 1964), and represents the trace of mantle attachment at the pallial line, being deposited below the pallial muscles. It is the 'pellucid layer' of Japanese workers (i. e. KOBAYASHI, 1964), the hypostracum of JAMESON (1912), LOWENSTAM (1964) and others, and the 'helle Schicht' of many workers. When sections are cut through the muscle scars, thick pads of similar myostracal prisms are seen, forming thick adductor myostraca. Small areas of myostracal prisms occur elsewhere in the shell, and are discussed below. These relations are summarised in Text figure 1.

In *Chama pellucida* there is an additional, outer layer, built of prismatic calcite. Within this there is a middle, crossed-lamellar layer, and an inner, complex crossed-lamellar layer, bordered by the trace of the pallial myostracum. These relationships are summarised in Text figure 2. *Chama pellucida* thus possesses an additional layer, not, as LOWENSTAM (1964) states, a layer which

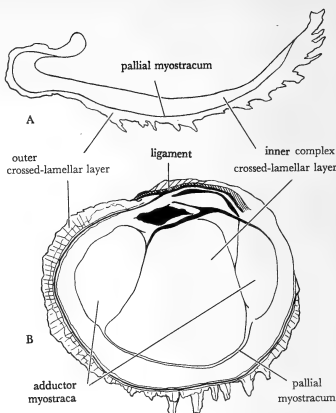


Figure 1
Distribution of shell layers in *Chama mactrophylla*
A - section B - shell interior

replaces the outer layer of wholly aragonitic species. The middle layer of *C. pellucida* is equivalent to the outer layer of other species of *Chama*.

Explanation of Plate 61

Figure 1: The contact of the middle crossed-lamellar layer and the adductor myostracum of *Chama radians*. Acetate peel of a radial section. $\times 100$

Figure 2: Radial section of the inner layer of *Chama lamellosa* showing complex crossed-lamellar structure and thin sheets of 'myostracal type' prisms. Acetate peel. $\times 100$

Figure 3: Transverse section of the outer, prismatic calcite layer of *Chama pellucida* showing the large irregularly prismatic blocks with much finer units within. Acetate peel. $\times 100$

Figure 4: Planar section of the outer prismatic, calcite layer of *Chama pellucida*. Sub-parallel finely prismatic units and growth bands are visible. Acetate peel. $\times 100$

Figure 5: Contact of the outer prismatic layer (above) and the middle crossed-lamellar layer (below) in *Chama pellucida*. Growth bands are continuous between layers. Crossed-lamellar structure is seen in the lower right hand corner of the picture, the transition zone between the layers is homogeneous and rich in organic matrix. Acetate peel. $\times 100$

Figure 6: The inner complex crossed-lamellar layer of *Chama pellucida* showing myostracal pillars. Acetate peel. $\times 100$

Figure 7: Myostracal pillars in the inner complex crossed-lamellar layer of *Chama radians*. Acetate peel of a radial section. $\times 100$

Figure 8: Planar section through the adductor myostracum of *Chama lazarus*. Acetate peel. $\times 100$

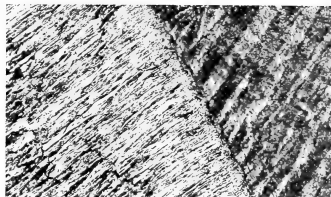


Figure 1

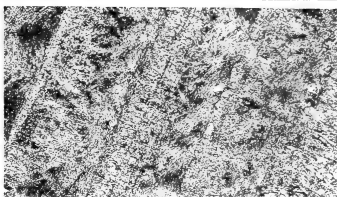


Figure 2

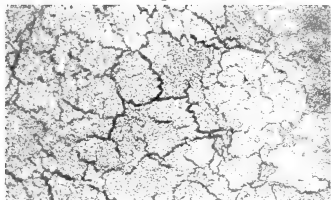


Figure 3

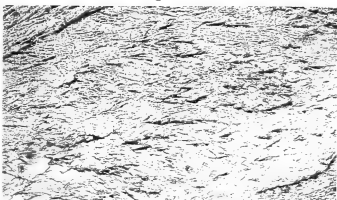


Figure 4

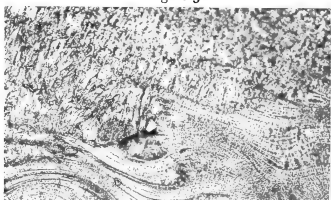


Figure 5



Figure 6

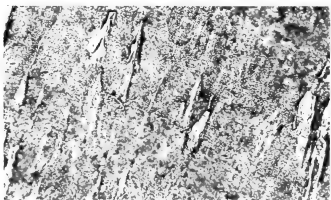


Figure 7

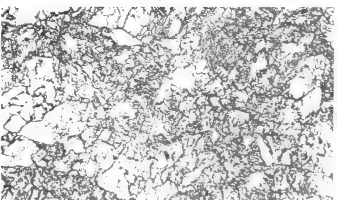


Figure 8



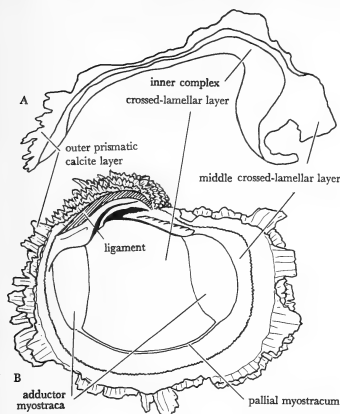


Figure 2

Distribution of shell layers in *Chama pellucida*

A - section B - shell interior

The structure of the various parts of the shell is described below.

STRUCTURE OF THE CROSSED-LAMELLAR LAYER

Conventional microscopy shows the inner surface of this layer as a series of elongate, branching and interdigitating lenses. These are arranged with their long axes running concentrically, parallel to the shell margins. These lenses are the first order lamels of BØGGILD (1930). In sections, these lamels run normal to the inner surface of the shell layer, although often bending and turning towards the outer surface of the shell. They often branch and inter-

digitate, producing a strong interlocking structure (Plate 64, Figures 20, 21).

Thin sections and peels of this layer show a very striking colour pattern, with adjacent first order lamels being either straw or red-brown in colour.

Lamels may be up to several millimeters long, and are usually of the order of 0.5 mm wide. Sections of the umbonal region show a characteristic pattern of diverging primary lamels.

Internal structures of first order lamels are not easily resolved at optical level. It can be seen, however, that each first order lamel is built of second order lamels which are inclined to the shell interior, with opposed directions of inclination in adjacent first order lamels. Each second order lamel appears to be built of smaller laths, joined in side-to-side contact. Becke line studies reveal that the whole of the crossed-lamellar layer is an intergrowth of aragonite crystals in only two crystallographic orientations.

These observations are confirmed and extended by electron microscopy (Plate 62, Figure 12). These results are summarised in Text figure 3. Thus the whole layer can be seen to be built of minute laths, lying parallel within each first order lamel, and joined into sheets. These laths are up to 1μ in diameter, and some tens of

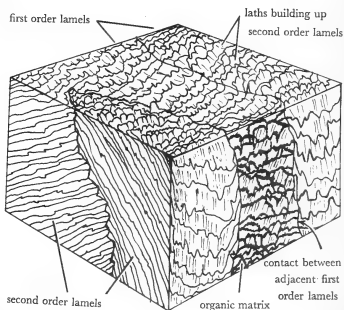


Figure 3

Block diagram of crossed-lamellar structure, based on electronmicrographs

microns long. Etching reveals the presence of lace-like membranes within the crossed-lamellar layer; these correspond to the proteinaceous organic matrix well known in molluscan nacre and prisms. (GRÉGOIRE, 1967, with references.)

STRUCTURE OF THE COMPLEX CROSSED-LAMELLAR LAYER

Peels and thin sections (Plate 61, Figures 2, 6, 7) show that this layer is built up of the same basic elements as crossed-lamellar structure, i. e., laths arranged into second order lamels. These are not arranged into lenticular first order lamels, but form irregular interdigitating blocks, with lamel attitudes similar within blocks, but opposed

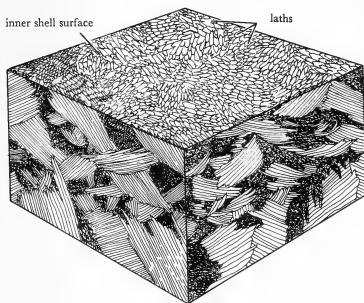


Figure 4

Block diagram of complex crossed-lamellar structure,
based on electronmicrographs

in adjacent blocks. Sections show areas of granular appearance between blocks which have a distinct lamel structure within them, and since this pattern is seen in sections cut in all orientations, we conclude that this layer type is built up of second order lamels inclined in many directions. Electronmicroscopy confirms these observations (Plate 62, Figure 9), and also shows the presence of lace-like organic matrix within the complex crossed-lamellar structure. This structure is shown diagrammatically in Text figure 4.

STRUCTURE OF THE PRISMATIC LAYER

In hand specimens, this layer has a distinctive translucent, 'pellucid' appearance, and gives *Chama pellucida* its specific name. The outer layer is projected into a series of irregular folia and squamae. At optical level (Plate 61, Figures 3, 4, 5) this layer has a grey appearance, and is built up of minute blade-like prisms, arranged more or less normally to the shell interior margin at the time of secretion. These minute prisms are variable in their attitude, and are arranged into longer irregular blocks. Under polarised light, these blocks go into extinction very irregularly, and there is thus no uniformity of orientation within the blocks.

This structure is markedly different from that of the calcite prismatic layer of most other bivalves, in that thick conchiolin walls are not developed between prisms.

There is a variable relationship at the contact between the prismatic layer and the crossed-lamellar layer. The inner surface of the prismatic layer shows irregular corrugations arranged radially from the umbo which are impressions of radial musculature of the mantle. Over wide areas of the contact there is a marked discontinuity with a zone of fine-grained aragonite, rich in organic matrix (Plate 64, Figures 21, 22, 23). This fills up the underlying grooves in the corrugated surface. Elsewhere, minute angular calcite crystals project into the outer part of the aragonite crossed-lamellar layer (Plate 64, Figure 22).

Explanation of Plate 62

Figure 9: Scanning electronmicrograph of a fractured section of the inner complex crossed-lamellar layer of *Chama macerophylla*. Parts of three blocks of parallel laths are shown, the inclination of laths in each block is different. $\times 550$

Figure 10: Scanning electronmicrograph of a polished, HCl-etched section of the crossed-lamellar layer of *Chama pellucida* showing sheets of fenestrate organic matrix. $\times 1400$

Figure 11: The inner surface of a myostracal pillar in the inner layer of *Chama macerophylla*. Note the irregular form of the myostracal pillars and grooves between the prisms. Scanning electronmicrograph. $\times 200$

Figure 12: Fractured section of the crossed-lamellar layer of *Chama macerophylla*. The contact of two first order lamels is shown, the second order lamels and laths of each first order lamel are inclined in opposed directions. Scanning electronmicrograph. $\times 1100$



Figure 9

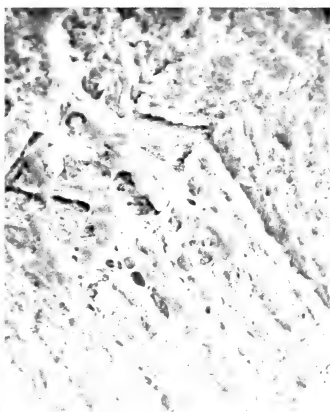


Figure 10



Figure 11



Figure 12



The crossed-lamellar layer must thus grow over an angular irregular prismatic surface.

Electron microscopy confirms these observations. Fractured sections show the larger prismatic blocks, with prominent transverse striations (Plate 63, Figure 16). These are obviously built up of smaller elements. On the inner surface of the shell layer, these blocks are not distinct; all that can be made out is an irregular surface of small pyramidal mounds and small granules (Plate 63, Figure 13). These correspond to the outcrop of the smaller prismatic units seen at optical level.

Etching of sections brings out details not seen at optical level. Thus the fine prisms appear as elongate blocks, whilst oblique sections show their outlines (Plate 63, Figure 14). Etching also reveals the presence of organic matrix, as reticulate lace-like sheets surrounding the prisms. This organic matrix is heavily developed at the contact with the crossed-lamellar layer, whilst the matrix of both layers appears to be in continuity.

STRUCTURE OF THE MYOSTRACA

The myostracal structure of all *Chamaea* is very similar. At optical level it has a characteristic grey colour, strongly contrasting with adjacent shell layers. The structure is built of prisms, which are highly variable and irregular in outline, with re-entrant angles (Plate 61, Figure 8).

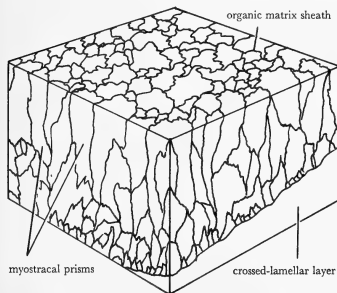


Figure 5

Block diagram of myostracum
based on electronmicrographs
is not shown

These prisms vary greatly in size, but are always oriented normal to the surfaces of the myostracum, with crystallographic *c* axes in the same direction. These relationships are summarised in Text figure 5. On shell interiors, myostracal prisms outcrop as minute irregular polygons.

Pallial and adductor myostraca are readily understood, being secreted below areas of undoubted muscle attachment. In the *Chamaea* myostracal structure is also developed as discrete sheets and pillars within the inner shell layer (Plate 61, Figure 2). Myostracal sheets of this type occur in some other bivalves, and we believe they may indicate sites of temporary mantle attachment, although conclusive evidence is lacking.

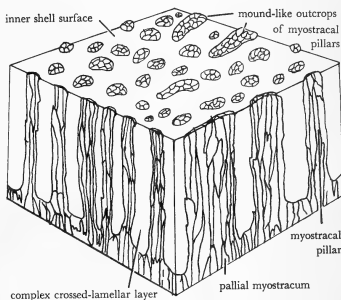


Figure 6

Block diagram of myostracal pillars.
The structure of the surrounding complex crossed-lamellar structure

Pillar-like structures (Plate 61, Figures 6 and 7), which we propose to refer to as myostracal pillars, are developed in most *Chamaea*. In peels and sections these appear as elongate columns, with the long axis normal to the shell interior. Serial sections reveal that these are in fact sections of continuous blocks of myostracum extending inwards from, and continuous with, the pallial or adductor myostraca (Text figure 6). On shell interiors these outcrop as minute bosses usually 0.5 to 0.1 mm across, sometimes arranged in rows which radiate from the apex of the shell. Plate 62, Figure 11 shows the surface of such a boss. Here it is clear that there is a series of discrete prisms,

separated by grooves (of uncertain origin). There are also traces of finer structure visible within the prisms.

Histological preparations of *Chama jukesii* show that the outer mantle surface is locally modified into papillae, as the result of elongation of the mantle cells. These papillae agree in size and shape with the myostracal pillars present in the inner shell layer of that species, and thus appear to represent the points of attachment.

TUBULES

The Chamacea all possess the remarkable shell feature described by OBERLING (1964) as tubules. These are minute cylindrical perforations, usually only a few microns in diameter, which open at the interior of the shell and penetrate the shell layers. These are undoubtedly a primary feature of the shell, not to be confused with algal borings or other perforations (OBERLING, *op. cit.*). The distribution of tubules is very constant in the Chamacea where they are largely confined to the inner shell layer.

At optical level tubules appear as minute, hollow, unbranched, straight cylinders, cutting the finest observable elements of shell structure.

At electron microscope level (Plate 64, Figures 17, 18, 19) the tubules are empty and unlined, and penetrate, but do not seem to disturb, shell fabric. Indeed, details of layering and fine structure are visible inside the tubule (Plate 64, Figure 18). The opening of the tubule is a distinct conical pit, and in some species of *Chama*, including *C. pellucida*, the tubules are grouped in minute oval depressions (Plate 64, Figure 17).

Figure 13: Scanning electronmicrograph of the inner surface of the outer prismatic calcite layer of *Chama pellucida*. The outcrop of the minute prisms building up this layer are shown. $\times 2100$

Figure 14: Polished, HCl-etched radial section of the outer prismatic layer of *Chama pellucida*. Scanning electronmicrograph. $\times 700$

Figure 15: Polished, etched section of the contact between the

We have been unable to determine the origin of tubules. Since they occur more abundantly in older parts of the shell, and in some species of bivalve are absent at the margin, they may be resorptive, but histological work on decalcified material has revealed only the ambiguous traces of mantle extensions into these holes.

DISCUSSION AND CONCLUSIONS

Chama pellucida has a shell structure which is comparable to that of all other species of Chamacea in many respects. It is, however, unique in possessing an outer, prismatic calcite layer. The middle shell layer is equivalent to the outer layer of all other species; there is no change in microstructure as LOWENSTAM (1963) has implied; a new outer layer appears in *C. pellucida*, which thus has a three layered, not a two layered shell.

It is also difficult to accept *Chama pellucida* as a wholly cold-water species of *Chama*, for it ranges across the equatorial belt.

We would therefore question previous interpretations of the structure of *Chama pellucida*, and without further evidence would doubt the validity of using it as an example of environmental controls on shell mineralogy.

This species is, however, quite unique amongst extant heterodonts in the development of calcite in its shell, and the significance of this is not understood. The calcite layer is, however, outermost, as is the calcitic shell layer in most other bi-mineralic bivalves. In common with *Chama pellucida* all other calcite bearing bivalves are epifaunal, or are derived from epifaunal ancestors.

Explanation of Plate 63

middle crossed-lamellar layer (above) and the pallial myostracum (below). Scanning electronmicrograph. $\times 700$

Figure 16: Scanning electronmicrograph of a fractured section of the outer prismatic calcite layer of *Chama pellucida*. Surfaces of larger prismatic units are visible, with distinct parallel, transverse striations. The finer prismatic units building the larger blocks are also visible. $\times 280$

Explanation of Plate 64

Figure 17: Inner surface of the inner complex crossed-lamellar layer of *Chama pellucida*. The openings of six tubules are visible, four lie together in an oval depression, two are in separate circular depressions. Scanning electronmicrograph. $\times 270$

Figure 18: Detail showing the opening of a single tubule. Note details of fine structure within the hole and the lack of an obvious lining. Scanning electronmicrograph. $\times 2750$

Figure 19: Fractured section of inner complex crossed-lamellar layer of *Chama pellucida* showing a tubule. Note the lack of lining and the absence of any change of structure associated with the tubule. Scanning electronmicrograph. $\times 2800$

Figure 20: Radial section of the middle crossed-lamellar layer of *Chama pellucida*. Bands of myostracal prisms representing the pallial and adductor myostraca are seen. Acetate peel. $\times 100$

Figure 21: Radial section of the contact between the outer calcite prismatic layer and the middle crossed-lamellar layer of *Chama pellucida*. Acetate peel. $\times 100$

Figure 22: As above, showing details of the highly irregular contact. The calcite prismatic layer (lower part of field) projecting into the crossed-lamellar layer. Acetate peel. $\times 100$

Figure 23: Radial section of the prismatic and crossed-lamellar layer contact, showing the irregular contact and an organic rich zone next to the prismatic layer. Thin section. $\times 100$

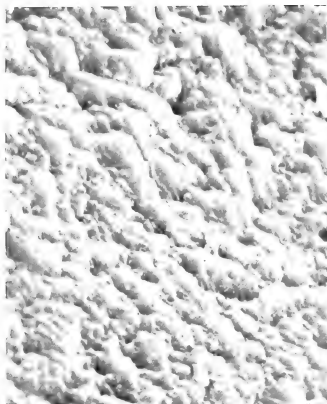


Figure 13



Figure 14

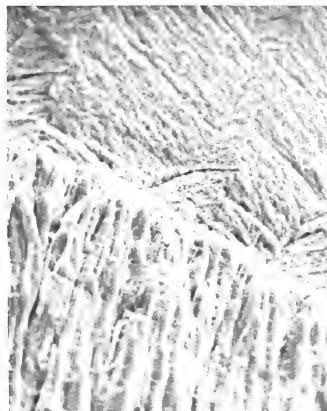


Figure 15



Figure 16



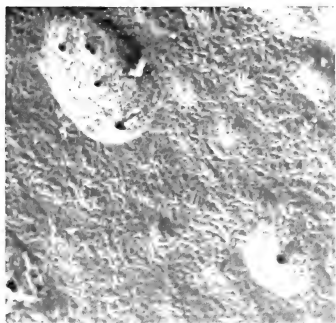


Figure 17



Figure 18

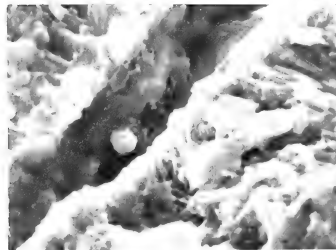


Figure 19



Figure 20



Figure 21



Figure 22

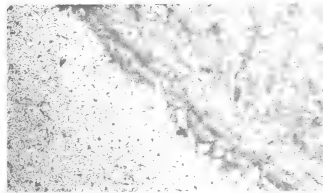


Figure 23



An interesting comparison comes from the extinct heterodont group, the rudists. These are derived from wholly aragonitic pachydonts such as *Megalodon* and *Pachyrisma* (Cox, 1960), but on assuming a cemented habitat, and developing massive shells, calcitic outer layers appear. This cannot, however, be taken as evidence for affinity between Chamacea and Hippuritacea as NEWELL (1965) or YONGE (1967) have suggested.

We also describe evidence for the local attachment of mantle to shell interior as demonstrated by the presence of sheets of myostracal prisms. Myostracal pillars and papillae on the mantle surface of *Chama jukesii* indicate continued attachment at localised sites with the pallial line throughout the life of the animal in this, and by inference, all other Chamacea.

ACKNOWLEDGMENTS

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APPENDIX

A calcitic outer layer is also present in specimens in the British Museum (Natural History) labelled *Chama exogyra* CONRAD, from California.

Examination of the type specimens of *Chama exogyra* CONRAD, 1837 and *C. pellucida* show that the specimens are distinctive. *Chama pellucida* is rounded in outline, 'normal' (i.e., attached by the left valve) and has striking translucent squamae. *Chama exogyra* is 'inverse' (attached by the right valve), irregular, elongate, and lacks conspicuous squamae.

Other specimens of *Chama exogyra* show rather more conspicuous ridges and cementation can take place by the left valve. 'Normal' specimens of *C. exogyra* closely resemble *C. pellucida* and 'inverse' specimens of *C. pellucida* closely resemble *C. exogyra*.

The similarity of the unusual shell structure together with the similar geographical range (YONGE, 1967) of these two species, taken together with the problems of inversion in the Chamacea makes us suspect that these species may be synonymous.

We believe that there is sufficient doubt of their validity to merit a field investigation of their relationships. We hope that this note will stimulate workers in California to investigate the problem.

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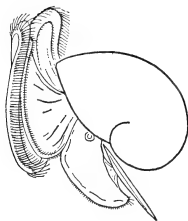
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Molluscan Faunas of Pacific Coast Salt Marshes and Tidal Creeks

BY

KEITH B. MACDONALD¹

Scripps Institution of Oceanography, La Jolla, California 92037

(1 Map)

INTRODUCTION

PACIFIC COAST *Spartina* - *Salicornia* salt marshes, and the tidal creeks that dissect them, contain distinctive molluscan faunas. The taxonomy of most of the species represented in these faunas is well documented (FITCH, 1953; PALMER, 1958; KEEN, 1958, 1963; HANNA, 1966) and in some cases papers describing aspects of the ecology of individual species, or of closely related species in other localities are available (e.g., HAUSEMAN, 1932; MACGINITIE, 1935; SANDER, 1950; YONGE, 1951; MEYER, 1955; SELLMER, 1967).

These faunas deserve further study, not only because they occupy habitats that are rapidly disappearing on the Pacific Coast, but because the huge species populations found at several sites may play an important role in the cycling of nutrients and detritus (organic debris) and thus indirectly affect offshore communities (NEWELL, 1965; CARRIKER, 1967; HEDGPETH, 1967).

This report outlines the geographic distribution and relative abundance of the species represented in these faunas. No previous studies of this subject have been found in the literature.

METHODS

Salt marshes and tidal creeks in 9 Pacific Coast bays and estuaries were examined (Figure 1). At 7 of these localities single sites were sampled. Local spacial variations were studied by sampling 2 sites at both Tomales Bay and San Quintin Bay. Ten of the sites were sampled only once, each sample-set being collected over a 2-3 day period. To provide a basis for separating real latitudinal differ-

ences from yearly population fluctuations, 5 replicate sample-sets were taken at Mission Bay, at approximately quarterly intervals (November 1964 to July 1966).

Individual sites were selected for a minimum of pollution and freshwater runoff. Isolated marshes that could be sampled as discreet units were preferred to artificially defined sections of more extensive marshlands.

At each site the vegetated marsh surfaces and tidal creeks were sampled independently. For the former, stratified random sampling patterns were set up (COCHRAN, 1954). Random number tables were used either to locate samples at random intervals paced along previously surveyed relief transects, or, to select pairs of random coordinates locating the samples within quadrants of a prescribed irregular area. The molluscan data were collected from stainless steel rings enclosing an area of 200 cm²; each sample was excavated to a depth of 1 cm.

At 9 of the sites the tidal creek samples were located at random intervals paced along the creek banks; at Grays Harbor and Mission Bay these samples were collected at fixed intervals. In most cases (cf. Table 2) the creek bottom mollusks were sampled from 25 × 25 cm quadrats excavated to a depth of approximately 25 cm. Upon return to the laboratory each marsh or creek sample was washed through a 1 mm mesh screen and all of its molluscan components were sorted, identified and counted (see MACDONALD, 1967, for additional details of sites and sampling methods).

RESULTS AND DISCUSSION

Seventy-six mollusk species were collected during this study; 64 of these were represented in the quantitative samples and the remainder were picked up during reconnaissance of the sites. In the samples, 2 species were represented by live specimens only, 28 species by both

¹ Present address: Department of Geology, University of California, Santa Barbara, California 93106

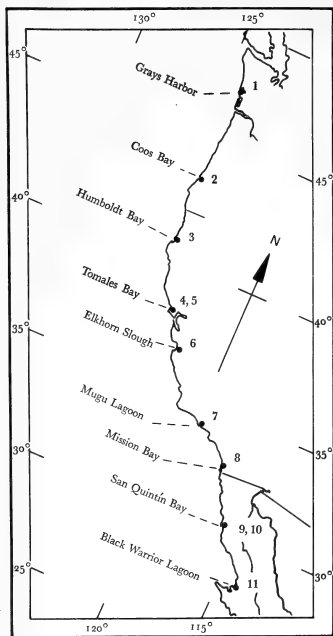


Figure 1

North American Pacific Coast,
showing the general location of the sites investigated

living and dead material and the remaining 34 species by empty shells only. Only the live material from the quantitative samples is considered in this report.

The geographic distribution and relative abundance (i. e., percentage of total individuals, per sample set) of

the mollusks represented in the live material are shown in Tables 1 and 2. Table 3 summarizes seasonal changes in the relative abundance of selected species in the replicate samples taken at Mission Bay.

ABUNDANCE

In sets of 25 - 178 samples, 2 - 7 species were found in the salt marshes and from 0 - 11 in the tidal creeks. The number of species increases significantly southward in the marsh environment (Kendall rank correlation procedure, $P < 0.05$, 1-tailed). There is similar increase in the tidal creeks, but largely because of the poor representation of mollusks at San Quintín Bay (KEEN, 1962), it is not significant ($P > 0.05$).

The mean density of mollusks (i. e., total individuals per sample set/combined area of samples) and the mean densities of separate species in both environments show no correlation with the number of species recorded from each marsh or creek, or with the latitude or area of the site being sampled. This suggests that the abundance of mollusks at a specific site is controlled by a variety of local factors (sediment type, food supply, etc.) rather than by regional trends of climatic or oceanographic variables.

The distribution of individuals between species exhibits a distinct pattern in the faunas of both environments: 90 - 100% of the individuals collected in each sample set belonged to 2 or 3 species; any additional species present were each represented by relatively very small numbers of individuals. Inspection of individual sample-sets also reveals that the abundant species were widely distributed at each site whereas the less common species had markedly patchy distributions. This pattern remains essentially the same despite differences in the latitude and area of the site and the species composition and density of the faunas.

SPECIES COMPOSITION

The creek faunas usually contain more species and have a more variable species composition than do those of the marshes. In part this may reflect the more highly specialized fauna of the latter, a marked contrast to that of the less extreme creek environments which contain a wide variety of species found in other barely subtidal habitats. Since a majority (83%) of the creek species are *infaunal* and thus subject to the selective effects of substrate (THORSON, 1957; PURDY, 1964) the compositional variability between sites might also reflect the variable nature of creek sediments. For example, at Tomales Bay shelly

Table 1
Salt Marsh Mollusk Faunas
Species Composition and Relative Abundance (i. e., percentage of total individuals per site)

Species	Locality ¹										
	1	2	3	4	5	6	7	8*	9	10	11
Gastropoda											
<i>Littorina newcombiana</i> (HEMPHILL, 1876)	90.6	52.3	0.3								
<i>Phytia myosotis</i> (DRAPARNAUD, 1801)	**	3.7	65.8	64.1	7.1	45.0					
<i>Assimineia translucens</i> (CARPENTER, 1864)	9.4	44.0	33.9	35.9	8.8	55.0	93.2	68.6	79.3	76.0	5.0
<i>Batillaria zonalis</i> (BRUGUIÈRE, 1792) †					84.1						
<i>Cerithiidea californica</i> (HALDEMAN, 1840)					*		5.9	28.2	20.0	17.1	34.5
<i>Melampus olivaceus</i> CARPENTER, 1857							0.8	0.9	*	0.3	32.4
<i>Littorina scutulata</i> GOULD, 1849							+	+			
<i>Acteocina culcitella</i> (GOULD, 1852)								2.0	0.7	5.5	
<i>Littorina planaxis</i> (PHILIPPI, 1847)								+			
<i>Acteocina carinata</i> (CARPENTER, 1857)											27.6
Bivalvia											
<i>Chione fluctifraga</i> (SOWERBY, 1853)								+			0.5
<i>Mytilus edulis</i> LINNAEUS, 1758								*			
<i>Ostrea lurida</i> CARPENTER, 1864								*			
<i>Lasaea subviridis</i> DALL, 1899										1.1	
Total individuals	553	300	693	245	309	5246	2282	2153	852	362	809
Marsh area (km ²)	0.237	0.071	0.056	0.111	0.046	0.104	0.886	0.139	0.060	0.019	0.099
Number of samples	50	59	40	49	20	45	60	100	50	20	50

¹ Localities as in Figure 1

+ = present, < 0.1% individuals per site

* = present at site but did not occur in samples

† = introduced species, not native to the West Coast

** = common at other sites around Grays Harbor

* Mission Bay values obtained from combined replicate sample sets

gravels were common, at Grays Harbor only coarse clean sands were present, at Coos Bay both soft muds rich in plant debris and firmer muddy sands were found and at the Humboldt Bay and San Quintín Bay sites almost liquid muds predominated.

The geographic distribution of recurrent groups of species supports the classification of Pacific Coast molluscan provinces proposed by VALENTINE (1966). Within the salt marsh faunas the Californian (27° - 34° N) and Oregonian (34° - 50° N) provinces are characterized by *Assimineia* - *Cerithiidea* and *Assimineia* - *Phytia* associations respectively.

The distribution of the more abundant tidal creek species suggests that the Oregonian Province can be further divided into 2 sub-provinces: the *Macoma* - *Mya* assemblage from Grays Harbor and Coos Bay, and represented by *in situ* empty shells at Humboldt Bay, characterizing a northern sub-province; the *Batillaria* - *Gemma* (both introduced species) assemblage from Tomales Bay

and Elkhorn Slough characterizing a southern one. The *Acteocina* - *Cerithiidea* association found in the tidal creeks south of Point Conception characterizes the Californian Province.

LOCAL VARIATION

Reconnaissance of different sites bordering the same bay or estuary indicates that the faunas of adjacent marshes or creek systems can vary considerably. Some of this variation reflects the environmental gradients characteristic of estuaries: for example, *Phytia myosotis* was not found at Westport but was common at other sites well within Grays Harbor (Markham, Oyhut), perhaps indicating a preference for less exposed or more brackish habitats. Conversely, *Littorina newcombiana* was very rare at Arcata but reached densities of 16 to 48 per m² on Samoa Marsh near the mouth of Humboldt Bay, suggesting a

Table 2
Tidal Creek Mollusk Faunas: Species Composition and Relative Abundance

Species	Locality ¹										
	1	2	3	4	5	6	7	8 ^a	9	10	11
Gastropoda											
<i>Littorina tenebrosa</i> (Hemphill, 1876)	0.7			92.2	63.9	43.0					
<i>Bartholomaeus</i> (BRODIE, 1792) †					0.1						
<i>Assiminea triducens</i> (CARPENTER, 1864)					*		84.4	28.2	3.5	78.0	74.4
<i>Cerithiidae californica</i> (HAIDEMAN, 1840)							11.5	68.7	29.4	22.0	
<i>Asteochia calicella</i> (GOULD, 1852)							0.1				
<i>Bulla gouldiana</i> PLUMMER, 1893								+			
<i>Siphonaria bransfordi</i> STEARNS, 1873									1.4		4.4 ^a
<i>Nassarius tegula</i> (REEVE, 1853)									67.1		19.4
<i>Brithium</i> sp.											
<i>Asteochia carinata</i> (CARPENTER, 1857)											
Bivalvia											
<i>Macoma triconchica</i> (BRODIE & SOWERBY, 1829)	77.5	7.2			0.1						
<i>Mya arenaria</i> LINNAEUS, 1758	4.2	71.4			0.1						
<i>Cryptomya californica</i> (CONRAD, 1837)	1.4										
<i>Macoma natua</i> (CONRAD, 1837)	16.2					+	0.6		*		
<i>Laternula japonica</i> (LISCHEKE, 1872) †		21.4									
<i>Gemma gemma</i> (TOTTEN, 1834) †				7.8	29.7	56.9			0.6		
<i>Modiolus senhousi</i> (BENSON, 1842) †					5.3	*					
<i>Protolotha staminea</i> (CONRAD, 1837)					0.6		2.8	0.2			
<i>Tapes japonica</i> DESHAYES, 1853 †					0.1						
<i>Mytilus edulis</i> LINNAEUS, 1758						+	0.1	*			
<i>Chione undatella</i> (SOWERBY, 1853)							0.4				
<i>Lyonsia gouldii</i> DALY, 1913								+			
<i>Chione fuchifraga</i> (SOWERBY, 1853)									0.6		1.3
<i>Tegulus californicus</i> (CONRAD, 1837)									0.3		0.4
Total individuals	142	14	0	490	1010	3179	720	5462	681	1496	227
Creek area (km ²)	0.026	0.006	0.003	0.008	0.004	0.004	0.045	0.003	0.003	0.001	0.003
Number of samples	20	29	16	18 ^a	5 ^a	20 ^a	15	78	10	4	10

¹ Localities as in Figure 1

For explanation of symbols, see Table 1

a: sample size 312 cm²; c: sample size 400 cm²; d: sample size 200 cm²; e: represented by *Nassarius tegula* (KINER, 1894), a possible subspecies.

Table 3
Mission Bay
Relative abundance of selected species in successive sample sets

	A	B	C	D	E
Salt marsh					
<i>Assiminea translucens</i> (CARPENTER, 1864)	58.6	59.5	58.2	80.2	
<i>Cerithidea californica</i> (HALDEMAN, 1840)	36.4	32.9	41.1	19.1	
<i>Acteocina culcitella</i> (GOULD, 1852)	0	7.2	0.7	0.3	
<i>Melampus olivaceus</i> CARPENTER, 1857	4.9	0	0	0.2	
Tidal creek					
<i>Acteocina culcitella</i> (CARPENTER, 1864)	77.0	45.7	66.5	85.4	61.1
<i>Cerithidea californica</i> (HALDEMAN, 1840)	19.9	50.0	30.4	13.0	35.9
<i>Nassarius tegula</i> (REEVE, 1853)	1.8	2.1	0.2	0.2	1.4

A = November 1964 (marsh samples hand-picked in the field, data found unreliable)

B = July 1965;

C = October 1965;

D = March 1966;

E = July 1966

preference for less brackish environments.

Data from Tomales Bay and San Quintin Bay suggest that differences of drainage pattern, substrate or vegetation can also account for local variability. The dominance of *Bittium* in the creek fauna of one of the San Quintin sites (10), for example, reflects the presence of dense *Zostera* (Eel-grass) beds, absent from the other site (9). Similarly, much of Millerton's (5) diverse fauna was collected from a network of narrow protected creeks with soft mud bottoms, while at Walker Creek (4) exposed, deep-water creeks with gravel bottoms were sampled. Possibly the highly dissected nature of the Millerton marsh also allowed *Batillaria* to remain closer to water sources and successfully colonize the marsh surface while it did not do so at either Walker Creek or Moss Landing (6).

SEASONALITY

Data from replicate samples taken at Mission Bay (Table 3) suggest that the relative proportions of the more abundant species remain generally similar throughout the year. Changes noted among the less common species probably reflect the sampling problems associated with rare or accidental species (e.g., *Bulla gouldiana*, *Littorina planaxis*, *Siphonaria brannani*), or with patchily distributed species (e.g., Index of Dispersion indicated that all the bivalve species were aggregated), rather than real compositional differences.

Seasonality was noted in *Melampus olivaceus* and *Nassarius tegula*. The former exhibited hibernation behavior similar to that described in *M. bidentatus* (HAUSEMAN, 1932) and was generally absent from the marsh surface

from about November through March. During this period many individuals were found clustered together in crab burrows 5-10 cm beneath the surface. *Nassarius* appeared to be a seasonal migrant into creek habitats rather than a permanent resident; January, March and October samples showed individuals to be restricted to the creek mouth, while in July they extended well upstream. The apparent seasonality of *Acteocina* in the marsh fauna marked the establishment of small temporary populations from larvae accidentally washed ashore.

Several new species records and range extensions have been noted during this study. For example, *Laternula* is not a native West Coast genus and the occurrence of *Laternula* sp., cf. *L. japonica* (LISCHKE) at Pony Slough, Coos Bay, Oregon, is the first known record of this species from the North American Pacific Coast. Occurrences of *Modiolus senhousei* (BENSON) at Elkhorn Slough and Mission Bay represent a considerable southward extension of the previously known West Coast range (36° to 48° N, HANNA, 1966) of this introduced species. The occurrence at Mission Bay of *Siphonaria brannani* STEARNS, previously known only from a single site near Santa Barbara (≈34° N; KEEN, 1937), also represents a range extension. Several of the salt marsh gastropods, *Assiminea translucens* (CARPENTER), *Phytia myosotis* (DRAPARNAUD) and *Littorina neucombiana* (HEMPHILL) were previously known only from scattered localities (TRYON, 1865; HEMPILL, 1876; BARTSCH, 1920; PAULSON, 1957; DUGGAN, 1965; HANNA, 1966); this study indicates that in fact these species are widely distributed on most marine marshes between latitudes 25° to 48° N, 35° to 49° N, and 41° to 47° N, respectively.

SUMMARY

Quantitative sampling at 11 sites between latitudes 27° to 48° N reveals that the molluscan faunas of Pacific Coast salt marshes and tidal creeks have a characteristic structure. At each site one or two species are widely distributed and very abundant; additional species are all represented by small numbers of very patchily distributed individuals. The creek faunas usually contain more species and have a more variable species composition than do the marsh faunas.

The geographic distribution of recurrent species groups supports the classification of Pacific Coast molluscan provinces proposed by VALENTINE (1966). There are some indications that both environments in the Californian Province (27° - 34° N) contain a greater variety of species than do similar environments in the Oregonian Province (34° - 50° N).

Now that the general composition of these faunas is known, their community interrelationships and ecological significance can be assessed through experimental studies of their more common species.

ACKNOWLEDGMENTS

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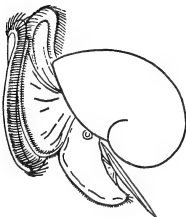
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The Type of *Tegula funebris* (A. ADAMS, 1855)

BY

RUDOLF STOHLER

Department of Zoology, University of California, Berkeley, California 94720

(Plate 65)

AS WAS SHOWN EARLIER (STOHLER, 1964), *Tegula funebris* (A. ADAMS, 1855) is a relatively variable species, even though, at the same time, it appears to be one of the least variable species of gastropods on the western coast of North America. This variability seems to apply only to two or, perhaps, three characters of the shell. One of these variable characters is the configuration of the base of the shell with which the paper already cited dealt. Another variable character seems to be the general shape of the shell. However, while the configuration of the base shows essentially the same type and range of variability from population to population, it would seem that the variability of the shape is limited to certain localities. This fact was also briefly mentioned in 1964.

In the latter part of August 1968 I had the opportunity to examine the type specimens of *Chlorostoma funebre* A. ADAMS, 1855 in the collection of the British Museum (Natural History) (Figures 1 to 3, Plate 65). It will be noticed that one of the 3 specimens (Figure 3) is very similar to the specimen illustrated in figure 2 of the earlier report. Unfortunately no exact type locality was given by ADAMS (1855, p. 317), only the very general statement "Hab. California."

After my return to Berkeley I re-examined the 596 specimens from 55 localities in the collection of the Department of Zoology at the University of California, Berkeley, with a view to measuring them and ascertaining

the height:width ratios of these shells. However, even a casual glance at the 7 specimens shown in Figures 4 to 10 on the accompanying plate reveals the utter futility of such an attempt. The extremely variable amount of damage done to the apex of the shells by the responsible fungus and other agents (see PEPPARD, 1964) could not possibly allow statistically valid measurements, calculations, and conclusions.

When, in spite of these acknowledged difficulties, I measured the figured specimens, it was done only for the purpose of ascertaining general trends in shell shape. The Table includes also the measurements obtained from the syntypes of the species in the BM(NH).

A careful examination of lots of specimens from a single locality shows that the shells of young animals have a lower H:W ratio, i. e., are relatively wider than older shells. There seems to be no correlation with geographical origin of the specimens. On the other hand, the specimens shown in Figures 3 and 8 are so similar in appearance and their respective H:W ratios that it becomes a great temptation to conclude that they come from the same locality, i. e., Duxbury Reef, Marin County, California. Yet the specimens shown in Figures 1 and 2 would fit very well into the population represented by the specimens pictured in Figures 4 and 5. These were collected at La Jolla, San Diego County. It seems more probable that the specimens

Explanation of Plate 65

Tegula funebris (A. ADAMS, 1855)

- Figure 1: Lectotype, *Chlorostoma funebre* A. ADAMS, 1855.
Cuming Collection, British Museum (Natural History) no. 1968208a
Figure 2: Paralectotype, BM(NH) no. 1968208b
Figure 3: Paralectotype, BM(NH) no. 1968208c
Figure 4: *Tegula funebris*, collected at La Jolla, California,
25 March, 1957; 30°52'N; 117°15'19"W; R. Stohler, coll.
Figure 5: Same data as for preceding figure

- Figure 6: San Simeon, California, 18 August 1947; 35°39'30"N;
121°14'W; R. Stohler, coll.
Figure 7: Same data as for preceding figure
Figure 8: Duxbury Reef, California, 30 October 1947; 37°53'N;
122°42'W; R. Stohler, coll.
Figure 9: Drakes Estero, California, 18 July 1947; 38°02'N;
122°56'W; R. Stohler, coll.

- Figure 10: Elk, California, 24 June 1947; 39°06'N; 123°42'30"W;
R. Stohler, coll.

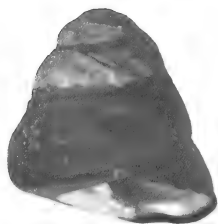


Figure 1

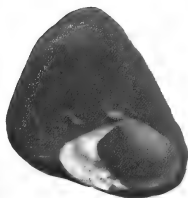


Figure 2

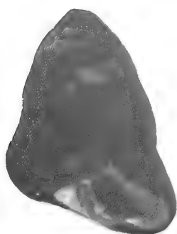


Figure 3

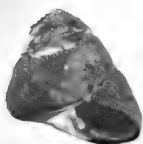


Figure 4

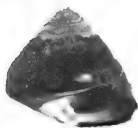


Figure 5

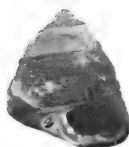


Figure 6

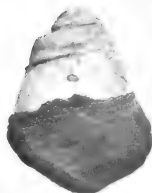


Figure 7

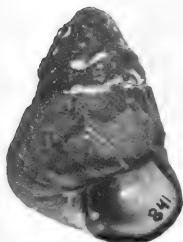


Figure 8

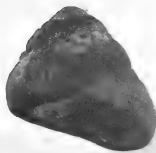


Figure 9

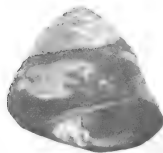


Figure 10



Table 1

Height and Width Measurements (in millimeters)
and Height:Width Ratios of Some Specimens
of *Tegula funebris*

	Height (mm)	Width (mm)	H:W
Figure 1	39.45	34.45	1.15
Figure 2	35.85	32.2	1.11
Figure 3	41.15	29.9	1.38
Figure 4	28.3	25.5	1.11
Figure 5	24.0	24.9	0.96
Figure 6	26.5	23.5	1.13
Figure 7	35.15	29.1	1.21
	18.25	18.3	0.99
	15.9	18.6	0.85
	11.1	12.8	0.87
Figure 8	43.85	31.0	1.41
Figure 9	26.9	28.0	0.96
Figure 10	28.75	29.7	0.97
	14.4	19.4	0.74
	14.0	17.8	0.79
	9.2	10.8	0.85

(Note: the data for shells following those for Figures 7 and 10, respectively, were obtained from specimens from the same locality.)

in the Cuming collection were actually obtained at or near San Diego, rather than at the northern site.

It has been emphasized earlier (STOHLER, 1964) that the tall and relatively slender specimens found in fairly large numbers at Duxbury Reef can always be picked out with ease in any general collection. A close comparison of Figures 3, 7 and 8 will, I believe, substantiate this claim, although possibly not as convincingly as the actual examination of specimens in large collections would.

Despite the unusually large and relatively slender specimens from near San Simeon in San Luis Obispo County,

I still maintain that the shape observed at Duxbury Reef is characteristic for the *Tegula funebris* population there. The specimen from San Simeon is but a single one in a lot of 6, where the remaining 5 conform more to the "normal" shape of the species, while the one from Duxbury Reef is one of a lot of 6, all of which are extremely similar to this one.

Since the type lot of ADAMS' species included 3 specimens, one of which exhibited a shape relatively rarely encountered in the field among large populations of *Tegula funebris*, I here select as the lectotype the shell illustrated in Figure 1 on Plate 65; the other 2 specimens are to be considered as paralectotypes. In my opinion the lectotype exemplifies the most commonly encountered representative of *T. funebris*, while the paralectotypes may be considered as illustrating the range of normal variability of adult specimens.

The lectotype has been given the number 1968208a, and the paralectotypes the numbers 1968208b & 1968208c, respectively, at the British Museum (Natural History).

ACKNOWLEDGMENTS

It is a pleasant duty to acknowledge the gracious courtesy with which the specimens and facilities at the British Museum (Natural History) were made available to me by Dr. Norman Tebble and Miss A. Fullick.

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The *Littorina ziczac* Species Complex

BY

THOMAS V. BORKOWSKI

Department of Biological Sciences, Florida State University, Tallahassee, Florida 32306^{1,2}

AND

MARILYNN R. BORKOWSKI

Bureau of Commercial Fisheries, Tropical Atlantic Biological Laboratory, Virginia Key, Miami, Florida 33149

(Plate 66; 4 Text figures)

INTRODUCTION

THE *Littorina ziczac* SPECIES COMPLEX has had a confused taxonomic history. The group has been described and figured by several authors since GMELIN (1791) (D'ORBIGNY, 1840, 1841; PHILIPPI, 1847, 1851; MÖRCH, 1876; TRYON, 1887; BEQUAERT, 1943; ABBOTT, 1964) and each has changed the nomenclature. TRYON placed them all under the name *Littorina ziczac* but indicated three varieties. BEQUAERT concurred and attributed the differences in shape and sculpture to sexual dimorphism; however, RODRIGUEZ (1959) stated that he could almost always separate the species into two forms showing different vertical distributions and FRAENKEL (1968) found two forms that differ in opercular structure. ABBOTT (1964), examining live material, concluded that there are two species, *Littorina ziczac* (GMELIN) and *L. lineolata* D'ORBIGNY, but from evidence given below, it will readily be seen that there are actually three species which are ecologically and morphologically distinct.

TAXONOMY

The three species of the *Littorina ziczac* species complex are: *Littorina ziczac* (GMELIN, 1791), *L. lineolata* D'OR-

BIGNY, 1840, and *L. lineata* D'ORBIGNY, 1841 (Plate 66). Partial synonymies are given for each species.

Littorina ziczac (GMELIN, 1791)

Trochus ziczak (pars) CHEMNITZ, 1781, Syst. Conchyl. Cab., 5, pl. 166, fig. 1599 [non-binomial]

Trochus ziczac GMELIN, 1791, in Syst. Nat., 13th ed., 1, prt. 6, no. 3587

Littorina zigzag D'ORBIGNY, 1842, In DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Moll., Atlas, pl. 15, figs. 5-8

Littorina debilis PHILIPPI, 1846, Proc. Zool. Soc. London for 1845, p. 140

Littorina d'Orbignyana PHILIPPI, 1847, Abb. Besch. Conch., 2: 162; pl. 3, fig. 12

CHEMNITZ in 1781 first figured *Littorina ziczac*, *sensu stricto*, and based his description on the descriptions of LISTER (1687) and FAVANNE (1784). But the name as given and spelled by CHEMNITZ must be considered incorrect because the International Commission of Zoological Nomenclature ruled that the first 11 volumes of CHEMNITZ' Conchylien Cabinet were nomenclatorially invalid (SCHENK & McMASTERS, 1948). LISTER's description is pre-Linnean while FAVANNE uses non-binomial names. Therefore, GMELIN's description and spelling of *L. ziczac* is the taxonomically valid citation for the species. D'ORBIGNY (1842) apparently used the names *zigzag* and *ziczac* interchangeably so that *zigzag* is to be considered only as an emendation of *ziczac*.

Examination of PHILIPPI's (1851) and TRYON's (1887) figures of *Littorina debilis* and PHILIPPI's (1847) figure of *L. d'Orbignyana* (which is *L. zigzag* D'ORBIGNY, 1842, Cuba p. 210, pl. 15, figs. 5-8) shows that these are synonyms of *L. ziczac* (GMELIN).

¹ This study is based upon a thesis submitted in partial fulfillment of the requirements of the Masters of Sciences Degree at Florida State University by the senior author.

² Present address: Institute of Marine Sciences, 1 Rickenbacker Causeway, Miami, Florida 33149

After some practice, this species can be easily distinguished from the other two species by its lighter color, smooth shell surface, microscopic spiral striations, dark nuclear whorls, and by its generally larger size. As will be seen later, vertical position on the shore and the presence of 2 color bands in the aperture are also useful discriminators.



Littorina lineolata D'ORBIGNY, 1840

Trochus ziczak (pars) CHEMNITZ, 1781, Syst. Conchyl. Cab. 5: plt. 166, fig. 1600 [non binomial]

Littorina lineolata D'ORBIGNY, 1840, Voy. Amér. Mérid., 5, prt. 3, Moll., p. 392

Littorina lineata (pars) D'ORBIGNY, 1841, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Moll., text p. 208; Atlas (1842), plt. 14, fig. 25 (not 24, 26-27)

Littorina lineata PHILIPPI, 1847, Abb. Besch. Conch., 2: 162; plt. 3, fig. 18 minor

Littorina jamaicensis C. B. ADAMS, 1850, Contr. Conch. 5: 71

Littorina floccosa MÖRCH, 1876, Malak. Blätter 23: 140

Littorina angustior var. *fasciata* MÖRCH, 1876, Malak. Blätter 23: 139

CHEMNITZ described and figured a variety of *Trochus ziczak* which he did not name and GMELIN, 1791, copied this description, but D'ORBIGNY named it in 1840. *Littorina jamaicensis*, as redescribed by MÖRCH, is *lineolata* and *L. floccosa* MÖRCH, 1876, must be considered a synonym of *L. lineolata* since MÖRCH considered *Trochus ziczak*, fig. 1600, and *L. lineata* D'ORBIGNY, fig. 25, as synonyms of *L. floccosa*. MÖRCH lists *L. lineata*, fig. 25, as a synonym for *L. angustior*, var. *fasciata*.

As TRYON indicates, this species is more ovate, with conspicuous striations. It is sometimes sharply keeled and has but one adapical color band in the aperture. The nuclear whorls are light colored and the columella tends to be a light brown or lavender, as opposed to dark brown in the other two. This species may also have a smooth grayish appearance due to erosion and the presence of boring fungi, but in this condition it cannot be mistaken for *L. ziczak*.



Littorina lineata D'ORBIGNY, 1841

Littorina lineata D'ORBIGNY, 1841, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Moll., text p. 208; Atlas plt. 14, figs. 24, 26-27 (not fig. 25)

Littorina carinata D'ORBIGNY, 1842, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, Moll. (not *Turbo carinatus* SOWERBY), Atlas, plt. 15, figs. 1-4; text p. 209

Littorina angustior MÖRCH, 1876, Malak. Blätter 23: 139

This species, although common and easy to find, has often been overlooked because of its smaller size and proximity to the other, more conspicuous species. D'OR-

BIGNY split it into 2 groups, keeled and unkeeled, and named them *carinata* and *lineata*, respectively. This distinction, however, cannot be consistently made, since the two extremes completely intergrade into one another. Either name, then, is applicable to the species. The name *carinata*, however, is a homonym to *Turbo carinatus* SOWERBY, 1819, which is also a littorinid, but not the same as *Littorina carinata* D'ORBIGNY (BEQUAERT, 1943). Therefore, the name *lineata* D'ORBIGNY, 1841 is the correct name, with the understanding that D'ORBIGNY's figure 25 is *lineolata*. It is unfortunate that the two names *lineata* and *lineolata* are so similar but D'ORBIGNY made it clear that he considered these different when he described *lineolata* in 1840 and considered *lineata* as a variety of *lineolata*. It is also unfortunate that PHILIPPI in 1847 redescribed *lineata* D'ORBIGNY in such a manner that *lineata* PHILIPPI is clearly a synonym of *lineolata*.

ABBOTT (1964) included *Littorina lineata* D'ORBIGNY within his concept of *L. lineolata* but has since agreed (personal communication) that this third species is valid and distinct. MÖRCH's and TRYON's figures and descriptions show that *L. angustior* is a synonym of *L. lineata*.

This species is exceedingly similar to *Littorina lineolata*, but several characters serve to separate them easily. *Littorina lineata* is generally smaller and darker than the other two, and has tendencies towards flattened whorls and straight rather than wavy or zigzag "flames." Its nuclear whorls are light and there are two or more color bands in the aperture. A melanic form of the species is found on the east coast of Florida and the Florida Keys.

DISTRIBUTION

The *Littorina ziczak* species complex belongs to the West Indian fauna, but it is also found all around the Caribbean and most of the Gulf of Mexico (HEDGPETH, 1953; BEQUAERT, 1943). It is not found on the Florida west coast and is absent from the Gulf coast of the United States as far west as Galveston, Texas, where it again becomes abundant. The complex extends as far south as Uruguay and as far north as Bermuda. All three species seem to occur together nearly uniformly, but collectors have not been aware of the three species within the complex and records are not always reliable.

On the Florida east coast, the three are distributed decidedly differently and show separate limits of northern and southern distributions (Text figure 1). The farthest north any of the three ranges is Cape Kennedy, where *Littorina lineolata* reaches its limit. Only occasional specimens of *L. lineata* are found north of Sebastian Inlet and *L. ziczak* seldom occurs north of Jupiter Inlet. On

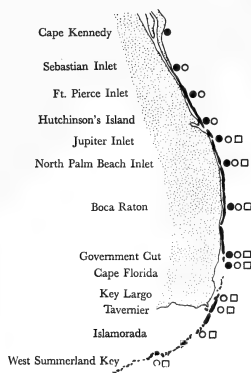


Figure 1

Species Distribution between Cape Kennedy
and West Summerland Key

● = *Littorina lineolata*; ○ = *Littorina lineolata*;
□ = *Littorina ziczac*

the other hand, *L. lineolata* occurs only sporadically south of Cape Florida on Key Biscayne, Miami, Florida.

These limits do not appear to be operable on the other side of the Florida straits. *Littorina ziczac* is abundant at Bermuda and *L. lineolata* is found throughout the Bahamas and the West Indies, as far south as Barbados. The mechanisms determining the distribution patterns on the Florida east coast are not known.

The vertical distributions of the three species are different, although all live supratidally in the splash zone. On the Florida coast, because of their latitudinal distribution, either *Littorina ziczac* or *L. lineolata* is often absent or poorly represented. In those areas where all 3 are well represented, the total number of animals is small or the substrate is so irregular that adequate transects are difficult to obtain.

Such results as have been obtained, however, indicate that the order of representation of the 3 species on the shore, from highest to lowest, is: *Littorina lineolata*,

L. lineolata, and *L. ziczac*. The distribution of each species overlaps those of the others somewhat and in areas where *L. lineolata* is absent, i. e., the Florida Keys, there is no gap in the distribution between *L. lineolata* and *L. ziczac*. Similarly, where *L. ziczac* is absent, *L. lineolata* extends as far down the shore as the barnacle zone (*Tetraclita* spp.).

Table 1

Vertical distribution of *Littorina lineolata*
and *Littorina lineolata* on beachrock at Boca Raton,
Florida, 14 August 1966

Distance (meters)	<i>Littorina</i>		
	<i>lineolata</i>	<i>lineolata</i>	<i>ziczac</i>
4.5	2	0	0
4.2	1	0	0
3.9	4	0	0
3.6	9	0	0
3.3	15	0	0
3.0	18	0	0
2.7	34	0	0
2.4	27	2	0
2.1	21	1	0
1.8	0	5	0
1.5	1	16	0
1.2	0	10	1
0.9	0	21	0
0.6	0	18	1
0.3	0	15	1
MHW	0	0	0

Table 1 indicates the distinctness of the vertical separation of *Littorina lineolata* and *L. lineolata* at Boca Raton, Florida. The supratidal zone at Boca Raton is considerably widened by wave action against a sandstone outcropping, which extends about 2 m above mid-tide level and the range of distribution extends considerably onto the top of the outcrop because of splash. In more sheltered areas, since the tidal range is less than a meter along most of the Florida coast, the vertical distributions are considerably compressed. The observed pattern is the same regardless of exposure or type of substrate (i. e., sandstone, coral limestone, broken concrete granite, cement bags, etc., incorporated into jetties, sea walls, or composing natural formations) (BORKOWSKI, 1967). The pattern is not changed when *L. ziczac* replaces *L. lineolata*.

SHELL MORPHOLOGY

The three species are statistically distinct in shell character measurements. Less than one misidentification in 1000 is likely if shell measurements alone are used.

The procedures of KIM, BROWN & COOK (1964, 1966) were used to select key characters for the 3 species, those characters with low intercharacter correlation and probability of misclassification. Shell characters for analysis were chosen on the basis of their importance in describing shell shape as discussed by FRETTER & GRAHAM (1962). These were: height; height/width ratio; aperture diameter; ratio of suture-to-suture whorl widths; spire angle; angle of the parietal wall from the axis; and angle at the keel (Text figure 2). The characters, lines/millimeter and

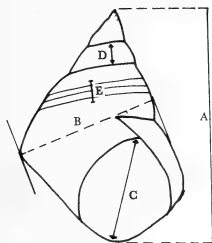


Figure 2

Measurements for Statistical Comparisons

A - height; B - width; C - aperture diameter; D - whorl width;
E - lines per millimeter

number of zigzags per whorl, were added as possible specific discriminators. Distances were measured by sliding scale Vernier calipers, accurate to 0.1 mm, supplemented by a pair of small cartographer's dividers on smaller distances, and angles were measured by a protractor accurate to one degree.

Accuracy of measurement was checked by measuring 10 specimens 5 times for each character, each measurement of a character separated by a sufficient time lapse to minimize repetitive measurement bias.

Specimens of *Littorina lineata* and *L. lineolata* were collected from Boca Raton beachrock, just north of the Boca Raton Inlet, on 29 April 1966. Several small, indiscriminately chosen areas were denuded of all animals until approximately 1000 animals had been collected, about 500 of each species. *Littorina ziczac*, s. s., was scarce at this collecting site, so that a somewhat smaller number had to be used, collected at various dates from the vicinity.

Table 2

Intercharacter correlation coefficients for
Littorina lineata, *Littorina lineolata* and *Littorina ziczac*

Variables	<i>Littorina</i>		
	<i>lineata</i>	<i>lineolata</i>	<i>ziczac</i>
Whorl ratio:			
spire angle	0.9	0.8	- .7
height	0.8	-0.1	-0.3
height-width	-0.7	—	—
aperture diameter	-0.7	0.0	0.4
lines/mm	-0.7	0.03	-0.7
flames	-0.8	-0.2	-0.8
angle parietal wall	1.0	0.1	0.3
angle at keel	0.0	-0.5	-0.7
Spire angle:			
height	-0.9	-0.9	-0.9
height-width	0.8	-0.2	-0.8
aperture diameter	0.7	-0.9	-0.7
lines/mm	-0.3	0.4	-0.9
flames	0.8	0.2	-0.1
angle parietal wall	0.0	-0.9	-0.3
angle at keel	0.9	-0.98	-0.8
Height:			
height-width	0.7	0.6	0.9
aperture diameter	0.98	1.0	0.99
lines/mm	-0.9	-0.7	0.6
flames	0.97	0.97	0.8
angle parietal wall	0.9	0.3	0.5
angle at keel	0.9	0.9	0.97
Height-width:			
aperture diameter	0.9	-0.1	1.0
lines/mm	-0.7	-0.3	-0.2
flames	0.95	-0.4	-0.4
angle parietal wall	—	0.0	0.8
angle at keel	0.6	0.8	0.8
Aperture diameter:			
lines/mm	-0.9	-0.7	0.6
flames	0.99	-0.8	-0.1
angle parietal wall	0.7	0.6	0.0
angle at keel	0.8	0.9	0.7
Flames:			
lines/mm	0.7	-0.6	-0.1
angle parietal wall	0.7	0.6	0.3
angle at keel	0.4	0.2	0.3
Angle parietal wall:			
lines/mm	-0.6	0.0	0.2
angle at keel	0.8	0.95	0.4
Angle at keel:			
lines/mm	-0.7	-0.6	0.9

Table 2 shows intercharacter correlations for the three species; several characters appear promising as discriminators. The character pairs that may separate *Littorina ziczac* from the other two are: whorl ratio-spire angle,

height-lines/mm, aperture diameter-lines/mm, and angle at the keel-lines/mm. For *L. lineata*, whorl ratio-height, whorl ratio-aperture diameter, whorl ratio-angle at the parietal wall, spire angle-aperture diameter, spire angle-flames, spire angle-angle at the keel, height-width ratio-flames, and angle of the parietal wall-lines/mm, and perhaps whorl ratio-angle at the keel, appear promising. But for *L. lineolata*, whorl ratio-lines/mm and height-width ratio-aperture diameter are the only promising character pairs. Spire angle-height-width ratio, spire angle-lines/mm, aperture diameter-flames, flames-lines/mm, and flames-angle of the parietal wall, may discriminate among all three.

Further examination, however, indicates that height, height-width ratio, aperture diameter, angle at the keel, spire angle, and flames form a well-correlated unit. The 2 characters correlated to this unit and separating *Littorina ziczac* from the other two are lines/mm and whorl ratio. These are quite well correlated to one another so that one or the other may be useful as a key character when compared to the others on a common size scale such as height. None of the above characters seems useful for separating *L. lineata* from *L. lineolata*, but the lines in the aperture, not included in the correlations because of stable consistent differences, are very important in this respect.

Littorina lineolata has only one color line in the aperture. The other two species have 2 color lines in the aperture. *Littorina lineata* and *L. ziczac* may have 3 color lines depending on the darkness of the aperture pigment and its ability to make the zone below the keel opaque. *Littorina lineolata* seldom, if ever, shows more, or less, than one line in the aperture.

A triangular graph (Text figure 3), using percentages

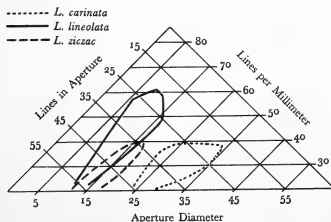


Figure 3

Multicharacter Comparison of the Three Species

of a combined total of 3 character values, shows the good discrimination among the 3 species when compared against a size parameter, in this case, aperture diameter. This result is based on data from specimens from several collecting stations and from different times of the year, as well as the original data, so that the result may be considered as indicative of actual species differences and not just 3 variants of one population. The values used for aperture diameter were restricted to the height range 6 - 12 mm to make the data comparable for the 3 species, but the normal size range of all 3 species does not differ considerably from this. The apparent overlap between *Littorina ziczac* and *L. lineata* on the triangular graph is not important if the size parameter is noted because the values for *L. ziczac* are overlapping those of much smaller *L. lineata*.

EGG CAPSULE DIFFERENCES

Another good species discriminator is the shape and size of the egg capsule. All 3 species release free-floating egg capsules of a uniform size and characteristic shape for each species (Text figure 4).

Egg capsules were collected on several occasions by putting freshly collected animals in a jar containing sea water overnight. The water was then examined for capsules which were measured, and drawn by aid of a camera lucida.

The capsules of *Littorina lineolata* are considerably different from those of the other 2 species. They are large and bell-shaped while the other 2 types are small and beehive-shaped. The absence of rings on the sides of the *L. ziczac* capsule is the most reliable characteristic in distinguishing the *L. lineata* and *L. ziczac* capsules. The ridges on the *L. lineata* capsule may occasionally be less distinct so that it closely resembles the *L. ziczac* capsule in general appearance.

The capsules of *Nodilittorina tuberculata* MENKE are very similar to the *Littorina lineata* capsules, although less so than the figures of ABBOTT (1954) would tend to indicate. In the *Nodilittorina* capsules, as seen from the side, the number of rings is 9 or 10. The *L. lineata* capsules have only 6 or 7, and the rings are farther apart.

All 3 capsules, *Littorina ziczac*, *L. lineata*, and *Nodilittorina*, may appear concentric or spiral from the top depending on the individual capsule and method of lighting the capsules when observing.

The 3 *Littorina* capsules have been figured in the literature under the name *L. ziczac*. LEBOUR (1945) figured the capsule of *L. ziczac* s. s., and LEWIS (1960) figured the capsules of *L. lineolata* and *L. lineata*, calling them

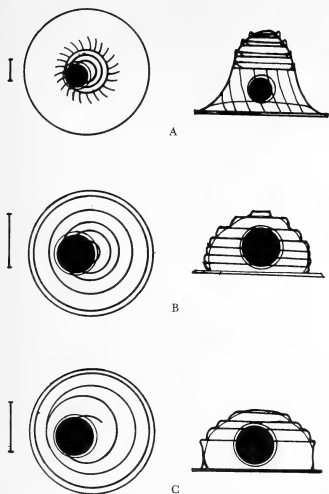


Figure 4

Egg Capsules of the Three Species

A = *Littorina lineolata*; B = *Littorina lineata*; C = *Littorina ziczac*
The line in each case represents one millimeter

large and small type *L. ziczac* capsules, respectively. ABBOTT (1954) and MARGUS & MARCUS (1963) figured the capsule of *L. ziczac*. ABBOTT in 1964 used these authors' figures as partial evidence that 2 species exist, but failed to distinguish between the LEWIS *L. lineata* capsule and the LEBOUR *L. ziczac* capsule.

CONCLUSIONS

Vertical and latitudinal distributions of the 3 species strongly indicate that each is a distinct ecological entity. *Littorina lineolata* has a more northern distribution in

Florida, while *L. ziczac* is found farther south, and *L. lineata* has a higher position on the shore than either. Three distinct egg capsule types furnish further proof of this distinctness.

Statistical testing for diagnostic characters has shown that the characters, lines in the aperture and spiral striae per millimeter, can distinguish among the 3 species with an error of less than one in a thousand.

Certain differences in the operculum and the reproductive structures have also been noted. These are currently being investigated and will be discussed in a later paper on the comparative anatomy of the tropical western Atlantic littorinids.

On this basis, it is evident that three species are present within the *Littorina ziczac* species complex bearing the names: *Littorina lineata* d'ORBIGNY, 1841; *L. lineolata* d'ORBIGNY, 1840; and *L. ziczac* (GMELIN, 1791).

ACKNOWLEDGMENTS

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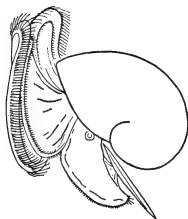
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Explanation of Plate 66

The *Littorina ziczac* species complex

Figures 1 & 2: *Littorina lineata* D'ORBIGNY, 1841

Figures 3 & 4: *Littorina lineolata* D'ORBIGNY, 1840

Figures 5 & 6: *Littorina ziczac* (Gmelin, 1791)

The lines on the figures equal one millimeter



Figure 1



Figure 2



Figure 3

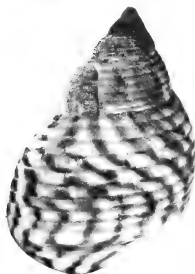


Figure 4



Figure 5



Figure 6



Spawning and Development in the Trochid Gastropod *Euchelus gemmatus* (GOULD, 1841) in the Hawaiian Islands

BY

THOMAS M. DUCH

Science Department, Bennett College, Millbrook, New York 12545

(2 Text figures)

THE PURPOSE OF THIS PAPER is to describe the breeding habits and development of the trochacean gastropod *Euchelus gemmatus* (GOULD, 1841) in the Hawaiian Islands. There are no previous reports of spawning periodicity or laboratory observations on the spawning behavior of a tropical trochid.

Euchelus gemmatus is a small (2 to 4 mm in height) trochid which is common in shallow water along the shorelines of the Hawaiian Islands. Large populations of this animal occur on the lower surfaces of dark, mottled rocks in tidepools and in shallow offshore waters where there is moderate turbulence. The snails are usually found congregated in crevices and beneath algae, but they are also able to cling to exposed rock surfaces.

METHODS

Forty animals averaging 2 to 4 mm in height were collected in October, 1965, and maintained in 2 one-gallon containers, 20 in a non-aerated jug and 20 in a container in which the turbulence of the natural habitat was simulated by means of an air stone. The animals were maintained in both situations for a period of 2 years and spawning and development occurred equally well among snails in both containers.

Egg masses which were deposited on the glass walls of the containers were removed by means of dissecting needles and placed on microscope slides which were set on a stand in a finger bowl. The egg masses were then easily removed for microscopic examination and could be replaced without injury. Daily changes of sea water and a soft jet of air bubbles directed onto the egg masses increased the survival rate of the developing embryos by reducing the numbers of ciliates which often congregate about the egg masses.

SPAWNING HABITS

Spawning in *Euchelus gemmatus* occurs from late December through April. The beginning of the spawning period is marked by the secretion of a gelatinous coat over the surface of the female shells; the covering remains on the shells throughout the spawning period. Subsequent to the appearance of the coat, pair formation occurs, a smaller male becoming attached to the left apertural sur-

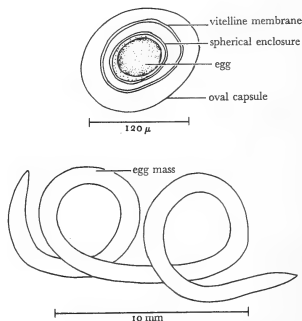


Figure 1

Euchelus gemmatus (GOULD, 1841)
Egg capsule and egg mass

face of the female shell. Because trochids presumably do not copulate, it is suggested that the male's position near the aperture of the female shell permits gametes to pass into the mantle cavity of the female.

During the period of observation 13 egg masses were deposited on flat surfaces from 1 to 5 cm above the surface of the water; the egg masses were deposited at twilight and at the time of high tide, with 9 of the egg masses deposited in March at the time of "extreme" high tide. After the initial spawning of one or two pairs of trochids, the remaining pairs spawned with increasing frequency.

Although it was difficult to observe egg deposition because of the initial transparency of the egg mass, it was possible to see the general pattern. Each female moves over a path about 15 mm in length in a counter-clockwise direction, depositing the egg mass (Figure 1). The egg masses are 3 to 14 mm in length, 2 to 3 mm wide, and about 1 mm thick, and they are deposited in the form of 3 to 5 loops. Females with smaller shells produce masses with fewer loops. The egg masses are flexible, jelly-like structures, enveloped by a thin, transparent integument which becomes translucent within an hour after deposition. The wall of the mass is tubulate and several layers of egg capsules are contained within the translucent matrix except at the tapered tips of the loop.

The eggs are brown and spherical, about 50 μ in diameter. Each egg is surrounded by a relatively homogenous sphere of albumen-like material, that nearest the egg semi-fluid and clear, the remainder more viscous. The egg and semi-fluid material are in turn surrounded by the vitelline membrane which is contained within a spherical elastic enclosure suspended in an outer oval capsule (Figure 1). The elastic enclosure stretches slowly as the embryo develops, exhibiting a fibrillar appearance. Prior to hatching, when the envelope is ripped by the embryo, the elastic enclosure almost fills the outer capsule. The capsules, which are closely packed within the matrix of the egg mass, are irregularly shaped because of crowding.

DEVELOPMENT

Early cleavage is initiated immediately after the egg mass is deposited. The first 2 cleavages are equal and occur within a few hours at a water temperature of 23°C. Subsequent cleavages result in the formation of large macromeres and small micromeres which envelop the macromeres, giving rise to the blastula within 2 days. A ciliated gastrula, which is flattened at the poles, develops during the next 2 or 3 days. The eggs at the surface of the egg mass are generally more advanced than are those near the center of the matrix.

The trochophore is recognizable 2 to 4 days after the egg mass is deposited and persists within the egg capsule for 3 to 5 days. The velar lobes are lightly pigmented and, although ciliated, the only noticeable motion is a slight vertical vibration. In the dorsal region a thickened clump of cells, the shell gland, becomes visible, and by the end of the third or fourth day this area of the embryo is covered by a thin sheet of shell matrix. The shell expands, occupying about $\frac{3}{4}$ of the dorsal surface, in a trochophore ready to metamorphose. Anterior and ventral to the visceral mass are 2 large, rounded protuberances which fuse, forming the foot of the veliger. As the foot develops, statocysts form as 2 elongated depressions behind the region of the mouth. There are 7 to 12 vibrating, calcareous grains in each statocyst, which gradually "sink" into the foot and are covered by pedal tissue. Rudiments of eyes, as 2 dark pigmented areas, are also visible at this period.

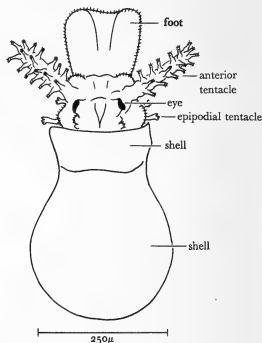


Figure 2

Euchelus gemmatus (GOULD, 1841)
Dorsal view of the late veliger stage

The veliger becomes recognizable 3 to 9 days after spawning, with a cap-like shell and anteriorly projecting foot (Figure 2). There is now a series of 5 protuberances: 3 small protuberances from which develop the epipodial tentacles and 2 larger protuberances which develop into the large anterior tentacles. Each protuber-

ance has a concentration of cilia about it, moving more or less in a counter-clockwise direction.

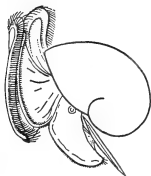
The visceral hump with its cap-like shell slowly shifts posteriorly, and torsion occurs within the next 24 hours. The shell seems to be deposited by the mantle as a thin translucent covering. Shortly after the translucent covering has been deposited, a shingle-like layer is deposited and continues to develop, soon occupying the entire dorsal surface behind the prototroch. On the posterior side of the foot a thin functional operculum develops, which in a short time is large enough to close the aperture of the shell. The operculum is first laid down as a series of "cellular" blocks which fuse and ultimately form the "true operculum." At the same time, the shell, which was very thin, becomes thicker and calcareous, with a furrowed surface.

As early as the second week of development, the veliger is seen actively moving about in the fluid of the egg capsule. The movement is generally limited to extending

and quickly retracting the foot into the shell. The retractive response seems to be associated with changes in light intensity and slight external vibrations. Shortly after, when the albumen-like material is gone, the veliger becomes very active and rips the egg capsule with its radula, leaving as a semi-crawling larva. Though the larvae are capable of darting movement, they remain relatively inactive, their movement localized to midway on the sides of the container. The larvae grow to 2 mm in height and, as the next breeding season approaches, the snails pair up and begin moving up and down the sides of the container with the times of the tides, laying egg masses in the same fashion as their parents.

ACKNOWLEDGMENT

I greatly appreciate the advice and comments of Dr. E. Alison Kay, University of Hawaii.



New Records of Nudibranchs from New Jersey

BY

ROBERT E. LOVELAND, GORDON HENDLER

AND

GARY NEWKIRK¹

Rutgers, the State University, New Brunswick, New Jersey 08903

IN A RECENT PAPER by FRANZ (1968), it was suggested that the paucity of records for species of nudibranchs occurring in New Jersey can be attributed to the absence of systematic and diligent collecting along the coastline. Although the general substrate of muddy-sand in New Jersey might restrict the number of species of nudibranchs, there are suitable outcroppings of man-made jetties and floating wharves where nudibranchs may occur. It is probable that new state records will occur for various kinds of invertebrates as collecting intensity increases. This was shown to be true for benthic, macroscopic algae by TAYLOR *et al.* (1968). The following list represents new information concerning the occurrence and distribution of nudibranchs along the Atlantic coast of North America.

NUDIBRANCHIA

DENDRONOTACEA

1. *Dendronotus frondosus* (ASCANIUS, 1774), as *Dendronotus arborescens* in MINER (1950). Occurrence: Shark River, April-May, 1968. Previous distribution, from Bay of Fundy to Long Island Sound (MOORE, 1964).

Many hundreds of this species were found in association with *Tubularia* on a floating wharf. Color ranged from nearly pure white to dark brown. ODHNER (1939) asserts that the white form of *Dendronotus* is predominant in deep water.

2. *Doto coronata* (Gmelin, 1791), as *Idulia coronata* in MOORE (1964). Occurrence: Shark River, May, 1968. Previous distribution, from Bay of Fundy to Long Island Sound (MOORE, 1964). Originally described from Great

Egg Harbor, New Jersey, by VERRILL & SMITH (1873), but rediscovered only recently.

DORIDACEA

3. *Acanthodoris pilosa* (O. F. MÜLLER, 1776), as *Doris pilosa* in ALDER & HANCOCK (1845-1855) and as *Doris bifida* in VERRILL & SMITH (1873). Occurrence: Delaware Bay, May, 1968. Previous distribution, throughout New England (MOORE, 1964). Reported, however, from Maryland by MARCUS (1961).

A single specimen of this dorid was collected from among unidentified encrusting ectoprocts on the back of a large *Limulus*.

EOLIDACEA

4. *Trinchia aurantia* (ALDER & HANCOCK, 1842), as *Eolis aurantia* in ALDER & HANCOCK (1845-1855), as *Montagua gouldii* in VERRILL & SMITH (1873), as *Catriona aurantia* in ABBOTT (1954), and as *Cratena aurantia* in MOORE (1964). Occurrence: Shark River, April-May, 1968. Previous distribution, from New Hampshire to Woods Hole (MOORE, 1964).

This species occurs commonly on the Connecticut shore on *Tubularia* (Franz, personal communication); however, this is the first instance of *Cratena aurantia* in New Jersey. Specimens were found in association with *Dendronotus frondosus* among thick growths of *Tubularia* on floating wharves, although its food source could not be ascertained.

5. *Eubranchia pallidus* (ALDER & HANCOCK, 1842), as *Eolis picta* in ALDER & HANCOCK (1845-1855) and as *Aeolis picta* in GOULD & BINNEY (1870). Occurrence: Shark River, February, 1967. Previous distribution, from Bay of Fundy to Rhode Island (MOORE, 1964).

This single specimen was found very low on the intertidal zone of an exposed jetty, among unidentified hydroids. It is interesting to note that *Lomentaria orcadensis*, a rare species of boreo-arctic algae for New Jersey, was

¹ We are indebted to Dr. David R. Franz, Biological Sciences, University of Connecticut, for criticizing this manuscript and for confirming our identifications. This work was supported, in part, by a grant from the Joint Investigatory Committee for Environmental Effects on Thermal Addition in Barnegat Bay.

also found from this same collection. Franz (personal communication) reports *Eubranchius pallidus* as being commonly found on *Obelia* along the Connecticut shore.

6. *Tergipes tergipes* (FORSKAL), as *Eolis despecta* in ALDER & HANCOCK (1845-1855), as *Aeolis despecta* in GOULD & BINNEY (1870), as *Tergipes despectus* in MOORE (1964) and in FRANZ (1968). Occurrence: Shark River, May, 1968; previously a single animal collected at Shark River by FRANZ (1968) in November, 1961. Previous distribution, from Bay of Fundy to Rhode Island (MOORE, 1964).

A second specimen of *Tergipes despectus* reported for New Jersey in 7 years qualifies this species as rare.

7. *Aeolidia papillosa* (LINNAEUS, 1761), as *Eolis papillosa* in ALDER & HANCOCK (1845-1855) and as *Aeolis papillosa* in GOULD & BINNEY (1870) and in MINER (1950). Occurrence: Shark River, May, 1965-1968; Manasquan River, May, 1967-1968; also reported by FRANZ (1968) for August, 1964. Previous distribution, from Bay of Fundy to Woods Hole (MOORE, 1964); from Greenland to Rhode Island (MINER, 1950). Franz (personal communication) reports this species as being common in Connecticut.

When first collected by Franz, this species was considered quite rare for New Jersey. It has been our experience that *Aeolidia* is rapidly becoming established in the estuaries of New Jersey as evidenced by its rather common occurrence in both Shark River and Manasquan Inlet during the spring of 1968 (Alan Schwartz, Rutgers University, personal communication). Specimens of 3-4 cm have been taken from both localities. Both of these inlets are characterized by water of high salinity and rock jetties. Although our records for this nudibranch are from the rocks, Schwartz reports these animals from within the estuary.

DISCUSSION

It is becoming more evident that the marine fauna of New Jersey, especially the nudibranch mollusks, represents a southern extension of the New England fauna, as was originally suggested by FRANZ (1968). It is not known, however, whether the species reported in this paper have recently invaded New Jersey or have been here unnoticed all along. Invasion by northern species of algae is apparently occurring, as in the case of *Codium fragile* (see TAYLOR, 1967). It is, therefore, possible that the eggs of nudibranchs, or the animals themselves, are being transported southward along the Atlantic coast by the same mechanism that is moving the algae. Once in New Jersey, they might then establish themselves in

the man-made, compatible habitats that are being rapidly established in this densely populated coastal state.

The white form of *Dendronotus* is reported generally from deep water (ODHNER, 1939). However, of the specimens collected in Shark River, at least 3 out of approximately 20 were of the white variety. All of these specimens were on floating wharves and, therefore, never deeper than several feet below the surface of the water. One white specimen has been sent to Dr. D. R. Franz of the University of Connecticut for further study.

We have included a listing of the nudibranchs reported to date from New Jersey in Table 1.

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Table 1

Checklist of Nudibranchs Reported for New Jersey

Species	Collected by	Location
SACOGLOSSA		
<i>Elysia catula</i> (GOULD, 1870)	VERRILL & SMITH (1873) F. Phillips (FRANZ, 1968)	Great Egg Harbor Barnegat Bay
<i>Elysia chlorotica</i> (GOULD, 1870)	VERRILL & SMITH (1873) K. Clark (FRANZ, 1968) FRANZ (1968)	Great Egg Harbor Cheesapeake Park Shark River
<i>Alderia modesta</i> (LOVÉN)	K. Clark (FRANZ, pers. comm., 1968)	Cheesapeake Park
NUDIBRANCHIA		
Doridacea		
<i>Acanthodoris pilosa</i> (MÜLLER, 1776)	Loveland <i>et al.</i> , 1968	Delaware Bay
<i>Doridella obscura</i> VERRILL	VERRILL & SMITH (1873) FRANZ (1967) LOWDEN (1966) as <i>Corambella baratariae</i> HARRY	Great Egg Harbor Delaware Bay Not given
<i>Polycerella emertoni</i> VERRILL	D. Dean (FRANZ, 1968) CHAMBERS (1934)	Raritan Bay Barnegat Bay
<i>Polycerella conyma</i> MARCUS	FRANZ (1968)	Jarvis Sound
<i>Tenellia fuscata</i> (GOULD, 1870)	CHAMBERS (1934) FRANZ (1968) Hendler (personal communication)	Barnegat Bay Shark River Delaware Bay
Dendronotacea		
<i>Doto coronata</i> (GMELIN, 1791)	VERRILL & SMITH (1873) Loveland <i>et al.</i> , 1968	Great Egg Harbor Shark River
<i>Dendronotus frondosus</i> (ASCANIUS, 1774)	Loveland <i>et al.</i> , 1968	Shark River
Eolidacea		
<i>Aeolidia papillosa</i> (LINNAEUS, 1761)	FRANZ (1968) Schwartz (Loveland <i>et al.</i> , 1968) LOWDEN (1966)	Shark River Manasquan Inlet Not given
<i>Cratena pilata</i> (GOULD, 1870)	FRANZ (1968) F. Phillips (FRANZ, 1968) Loveland <i>et al.</i> , 1968	Delaware Bay Barnegat Bay Shark River
<i>Trinchesia aurantia</i> (ALDER & HANCOCK, 1842)	Loveland <i>et al.</i> , 1968	Shark River
<i>Eubranchius pallidus</i> (ALDER & HANCOCK, 1842)	Loveland <i>et al.</i> , 1968	Shark River
<i>Tergipes tergipes</i> FORSKAL	FRANZ (1968)	Shark River

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Nomenclatural Changes for the New Species Assigned to *Cratena* by MACFARLAND, 1966

BY

RICHARD A. ROLLER

1127 Seaward Street, San Luis Obispo, California 93401

(2 Text figures)

FRANK MACE MACFARLAND'S POSTHUMOUSLY published volume on the opisthobranchiate mollusks of the Pacific coast of North America (1966) has been used by many research workers who felt the need for a comprehensive reference work on this group. The difficult task faced by the late Olive H. MacFarland in collating her late husband's notes and drawings was mentioned by G Dallas Hanna in his preface to the monograph, and he anticipated that corrections and additions might be required at a later date.

BURN (1968) commented on the need for Pacific coast workers to synonymize and validate the species described by MacFarland as new. The present contribution demonstrates the need for the generic transfer of 7 of these new species.

MACFARLAND (1966) introduced 7 new aeolid species (*abronia*, *albocrusta*, *flavovulta*, *fulgens*, *rutula*, *spadix*, and *virens*) and assigned them to the genus *Cratena* BERGH, 1864. Mrs. MacFarland added a note (op. cit., p. 332) that stated, "There is evidence among his notes and a letter from Nils Odhner that the author was carefully evaluating the status of the proper genus name for this group of aeolids prior to his death in 1951. However, the manuscript is published as left by him because he had not seen the later publications. The paper by WINCKWORTH (1941, pp. 146-149) in which *Catriona* is substituted for *Cratena* is especially significant."

Species of the genus *Cratena* have the cleioproct anal position; however, all 7 of the new species of aeolids described by MacFarland have the acleioproct anal position. Therefore the 7 species cannot be retained in *Cratena*.

Opinion no. 777 of the International Commission on Zoological Nomenclature (1966) added *Trinchesia* IHERING, 1879 to the Official List of Generic Names. In his proposal for stabilization of *Trinchesia*, LEMCHE (1964)

stated that "there is still the possibility that *Catriona* could be used for a genus . . . independently of *Trinchesia*." BURN (1964) and EDMUNDS (1968) maintained *Catriona* as a valid genus separate from *Trinchesia*, and several other specialists (personal communications) have concurred with this separation.

The two genera may be characterized as follows:

<i>Catriona</i>	<i>Trinchesia</i>
Acleioproct Eolidacea	Acleioproct Eolidacea
Radula uniseriate with cusp shorter than lateral denticles	Radula uniseriate with cusp as long as, or longer than, lateral denticles
Small secondary denticles interspersed among lateral denticles of radular tooth	No small accessory denticles among lateral denticles of radular tooth
Denticles on cutting edge of jaw in form of fine bristles, or bristled rodlets	Denticles on cutting edge of jaw not bristled

Of the 7 new species of MacFarland, 6 have the characteristic radular tooth shape and jaw denticulation of *Trinchesia*, while the remaining one has the radular tooth shape and jaw denticulation of *Catriona* (Figure 1). Therefore I propose that the following species be assigned to *Trinchesia*:

abronia, *albocrusta*, *flavovulta*, *fulgens*, and *virens*.

SPHON & LANCE (1968) synonymized *Cratena rutula* MACFARLAND, 1966 with *Catriona lagunae* (O'DONOGHUE, 1926). Since *C. lagunae* cannot be included in *Catriona* because of its typical *Trinchesia* radular tooth shape and jaw denticulation, it must be transferred to *Trinchesia* as a comb. nov., *Trinchesia lagunae* (O'DONOGHUE, 1926).

As shown in Figure 1, the radular tooth shape and denticulation of the jaw of *Cratena spadix* MACFARLAND, 1966 are obviously different from the remaining 6 species.

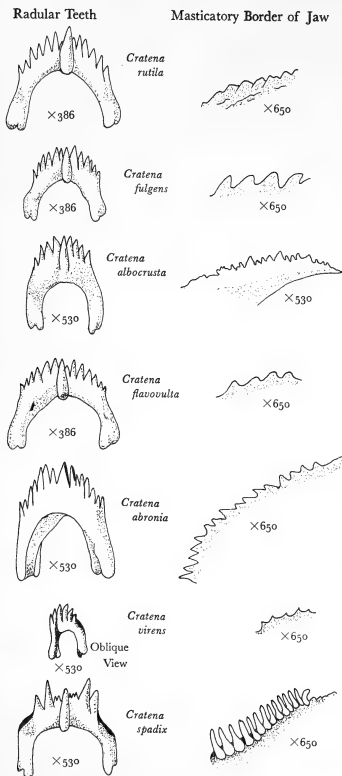


Figure 1

Specific differences of the species assigned to *Cratena* by MACFARLAND, 1966

MACFARLAND (1966, p. 354) notes that the penial stylet of *C. spadix* is not "as in the allied forms." This species was assigned to *Catriona* by EDMUNDS (1968).

SPHON & LANCE (1968) provided an "abbreviated synonymy" of certain of MacFarland's 1966 species. One of these species was *Cratena spadix* MACFARLAND, 1966 which they synonymized with *Cuthona alpha* BABA & HAMATANI, 1963. The findings below support their synonymy.

LANCE, (1966) reported the collection of 6 specimens of *Cuthona alpha* from San Diego, Newport Harbor, and Santa Barbara, California. All specimens were collected on boat landings in protected waters. The author collected 2 specimens of *C. alpha* on 9 February 1968 from boat landings in Morro Bay, California. They agreed with the description of the holotype of *C. alpha* as given by BABA & HAMATANI (1963). They also agreed with the description of *Cratena spadix* MACFARLAND.

Careful study of the descriptions of these two species showed them to be alike in almost all of their characteristics, but different in 2 important points: the presence or absence of a penial stylet, and differences in the masticatory margin of the jaw.

MACFARLAND in 1966 described the penial stylet of *Cratena spadix* as a "thin-walled chitinous armature which does not project beyond the surface of the tip as in the allied forms." BABA & HAMATANI (1963) described *Cuthona alpha* as a "mosaic species which has the decided radula type of *Catriona* on one hand, and the presumed penis peculiarity of *Cuthona* on the other hand." *Cuthona* was described as having an unarmed penis. The authors tentatively placed the species in the genus *Cuthona* ALDER & HANCOCK, 1855.

It appeared to the author that the 2 species might be synonymous, if *Cuthona alpha* did in fact possess a minute non-projecting stylet. This possibility was suggested to Dr. Baba, and upon re-examination (at high magnification) of paratype material he found a very short non-projecting stylet (personal communication).

EDMUNDS (1968) characterizes *Catriona* WINCKWORTH, 1941 as having "denticles on cutting edge of jaw in the form of fine bristles . . . short, straight stylet on penis." He assigned *Cratena spadix* to the genus *Catriona* and also proposed the possibility of the inclusion of *Cuthona alpha* in *Catriona*, "if details of the preradula and jaws were known, and if the genus were extended to include species without a penial stylet." The presence of a stylet in *Cuthona alpha* makes the extension of the genus *Catriona* unnecessary in order to include this particular species.

The masticatory margin of the jaw of *Cratena spadix*, as described by MACFARLAND (1966) was very different from the remaining 6 species of *Cratena* he described

at the same time. The margin of *C. spadix* was listed as bearing "a series of transverse rod-like thickenings which project beyond the margin as closely set blunt rodlets or ridges laterally in contact with each other . . . The rodlets are nearly straight near the hinge but become slightly curved as the tip is approached. At this tip, with high magnification, the surface seems to show minute spines."

In unpublished notes of MacFarland, a footnote by Mrs. MacFarland states, "With 5D magnification the surface of these rodlets at the lower end show a rough surface of minute spines. (Frank made one drawing)." This drawing (Figure 2) is reproduced herein for the purpose of augmenting MacFarland's original description, since this drawing was not included in the monograph.



Figure 2

Rodlets at lower end of masticatory margin of mandible
(from unpublished notes of F.M. MacFarland)

BABA (personal communication) re-examined paratype material of *Cuthona alpha*, and found that the denticulations of the jaw edge "appeared as if they were covered with short, thick bristles."

Members of the genus *Cuthona* ALDER & HANCOCK, 1855, are considered to have no penial stylet. Since *Cuthona alpha* is now known to have a short, straight stylet and bristled denticles on the jaw edge, the author proposes that the species be known by the new combination, *Catriona alpha* (BABA & HAMATANI, 1963).

I would like to thank Dr. Kikutarô Baba for his kind assistance in this study, and also Mr. Allyn G. Smith of the California Academy of Sciences who made it possible for me to use the unpublished notes of Dr. and Mrs. F. M. MacFarland.

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An Annotated List of Opisthobranchs from San Luis Obispo County, California

BY

RICHARD A. ROLLER

1127 Seaward Street, San Luis Obispo, California 93401

AND

STEVEN J. LONG

126 Esparto Avenue, Pismo Beach, California 93449

(1 Map)

TO DATE VERY LITTLE INFORMATION has been published on the opisthobranchs of San Luis Obispo County, California. MACFARLAND (1925), HANNA (1951), and STEINBERG (1963a) have mentioned single species collected from the county. LANCE (1961) and STEINBERG (1963b) include the county within the scope of their distribution lists. However, most studies of California opisthobranchs have been done in the Dillon Beach, San Francisco Bay, and Monterey Bay areas to the north, and in the Santa Barbara, Laguna Beach, and San Diego areas to the south, leaving a gap in data for the central coast area.

This list is an attempt to fill that gap and to add to the data recently reported by SPHON & LANCE (1968) for the southern bordering county, Santa Barbara. We have tried to continue their basic format, so that both lists may be used conveniently by workers of the central coast area. The present list, together with the lists of BROOKSHIRE (1968a, 1968b) form a reasonably complete catalog of the molluscan fauna of San Luis Obispo County.

Specimens were collected during field trips made by the authors, either jointly or separately, over a 2-year period. The entire coastline of the county was considered for possible collection sites, and 7 general localities were chosen (see Map, Figure 1). The coastline north of San Simeon is practically inaccessible except by boat, and only sandy beaches are found south of Shell Beach. Adjacent collecting sites of similar habitat were joined under one locality name. Most of the specimens were collected from the intertidal region; however, an attempt was made to include ecologically different regions (e. g., mud flats, boat docks) in the collections.

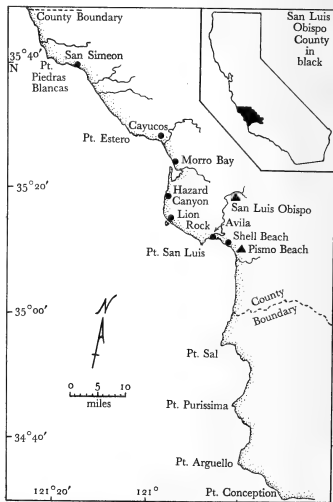


Figure 1

San Luis Obispo County, California - Collecting Stations

Of the 67 species listed, 62 species represent new records for the county. Only *Acanthodoris lutea*, *Aldisa sanguinea*, *Bulla gouldiana*, *Trinchesia abronia*, and *Trinchesia lagunae* have been recorded previously from the county.

The currently known range of each species is listed; range extensions, indicated by an asterisk (*) preceding their names, are included for the following species:

Acanthodoris nanaimoensis, *Cadlina sparsa*, *Doto kya*, *Pleurobranchus californicus denticulatus*, *Trapania velox*, and *Trinchesia flavovoluta*.

We have used the designations of SPHON & LANCE (1968) for the relative abundance of each species, and we must reiterate that these designations are arbitrary. No quantitative data are published for different habitats, seasonal fluctuations, or distribution within the county.

The names used for the species are the most currently accepted ones, and are the same as those used by SPHON & LANCE (1968), except for the following changes:

Archidoris odhneri (= *Austrodoris odhneri*)
Catriona alpha (= *Cuthona alpha*)
Doridella steinbergae (= *Corambella steinbergae*)
Doriopsilla albopunctata (= *Dendrodoris albopunctata*)
Trinchesia albocrusta (= *Catriona albocrusta*)
Trinchesia lagunae (= *Catriona lagunae*)
Chromodoris macfarlandi (= *Glossodoris macfarlandi*)
Hypselodoris californiensis (= *Glossodoris californiensis*)
Hypselodoris porterae (= *Glossodoris porterae*)

A list of inferred species, which may occur along the San Luis Obispo County coastline, follows the list of collected species. These inferred species were reported previously in the literature.

We acknowledge the assistance of Mr. Gary McDonald in furnishing collecting data and specimens.

LIST OF COLLECTED SPECIES

Acanthodoris lutea MACFARLAND, 1925

Frequent. Intertidal to 30 feet.

Cayucos, Lion Rock, Hazard Canyon, Shell Beach.

Dillon Beach to Point Loma.

* *Acanthodoris nanaimoensis* O'DONOGHUE, 1921

Rare

Shell Beach.

Vancouver Island to Shell Beach (Vancouver Island to Moss Beach).

Acanthodoris rhodoceras COCKERELL & ELIOT, 1905

Avila, Shell Beach.

Frequent

Dillon Beach to Coronados Islands.

Aegires albopunctatus MACFARLAND, 1905

Common. Intertidal to 20 feet.

Morro Bay Docks, Hazard Canyon, Shell Beach.

Vancouver Island to Coronados Islands; Bahía de Los Angeles

Aeolidia papillosa (LINNAEUS, 1761)

Frequent

San Simeon, Cayucos, Morro Bay Docks, Hazard Canyon, Lion Rock, Shell Beach.

Cosmopolitan.

Aglaja ocelligera (BERGH, 1894)

Rare

Morro Bay mud flats.

Alaska to Santa Barbara.

Aldisa sanguinea (COOPER, 1862)

Frequent

Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Bodega Bay to San Diego; Japan.

Ancula lentiginosa FARMER & SLOAN, 1964

Rare. On pulled wharf pilings.

Avila (Port San Luis Wharf).

Monterey Yacht Harbor to Bahía de Los Angeles.

Ancula pacifica MACFARLAND, 1905

Frequent

Hazard Canyon, Avila, Shell Beach.

Moss Beach to Point Loma.

Anisodoris nobilis (MACFARLAND, 1905)

Common. Intertidal to 50 feet.

Cayucos, Lion Rock, Hazard Canyon, Shell Beach.

Vancouver Island to Coronados Islands.

Antipella barbarensis (COOPER, 1863)

Frequent

Morro Bay Docks, Hazard Canyon.

Vancouver Island to Bahía San Quintín.

Aplysia californica COOPER, 1863

Common

Morro Bay mud flats.

Humboldt Bay to Gulf of California.

Archidoris montereyensis (COOPER, 1862)

Frequent

Cayucos, Morro Bay Docks, Hazard Canyon, Lion Rock, Shell Beach.

Alaska to San Diego.

Archidoris odhneri (MACFARLAND, 1966)

[see BURN, 1968]

Rare Subtidal from 20 feet.

Avila, Shell Beach.

Monterey Bay to Santa Barbara.

Berthella californica (DALL, 1900)

Frequent

San Simeon, Cayucos, Shell Beach.

Crescent City to San Diego.

Bulla gouldiana PILSBRY, 1893

Frequent

Morro Bay mud flats.

Morro Bay to Baja California.

Cadlina flavomaculata MACFARLAND, 1905

Common

Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Vancouver Island to Point Eugenia, Mexico.

Cadlina luteomarginata MACFARLAND, 1966

Common

Hazard Canyon, Lion Rock, Avila, Shell Beach.

Vancouver Island to Point Eugenia, Mexico.

Cadlina modesta MACFARLAND, 1966

Common

San Simeon, Cayucos, Hazard Canyon, Avila, Shell Beach.

Monterey Bay to La Jolla.

* *Cadlina sparsa* (ODHNER, 1921)

Rare

Morro Bay Docks, Hazard Canyon, Avila.

Morro Bay to Juan Fernandez Island, Chile. (Santa Barbara to Juan Fernandez Island, Chile).

Capellinia rustya MARCUS, 1961

Frequent

Morro Bay Docks, Hazard Canyon.

San Francisco Bay to Bahía de Los Angeles.

Catriona alpha (BABA & HAMATANI, 1963)

[see ROLLER, this issue]

Rare

Morro Bay Docks.

Monterey Bay to San Diego; Japan.

Corambe pacifica MACFARLAND & O'DONOGHUE, 1929

Common. On bryozoan colonies on offshore kelp.

Morro Bay Docks.

Vancouver Island to San Diego.

Coryphella trilineata O'DONOGHUE, 1921

Common

Cayucos, Morro Bay Docks, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Vancouver Island to Coronados Islands.

Dendronotus albus MACFARLAND, 1966

Frequent

Hazard Canyon, Lion Rock, Avila, Shell Beach.

Monterey Bay to Santa Barbara.

Dendronotus frondosus (ASCANIUS, 1774)

Common

Morro Bay Docks, Hazard Canyon, Lion Rock, Shell Beach

Cosmopolitan in northern hemisphere.

Dendronotus subramosus MACFARLAND, 1966

Common

Hazard Canyon, Shell Beach.

Humboldt Bay to Newport Bay.

Diaulula sandiegensis (COOPER, 1862)

Common

San Simeon, Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Japan to Cape San Lucas.

Dirona albolineata COCKERELL & ELIOT, 1905

Rare

Shell Beach.

Puget Sound to San Diego.

Dirona picta MACFARLAND in COCKERELL & ELIOT, 1905

Common (to 100 mm long)

Morro Bay Docks, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Dillon Beach to Point Loma.

Discodoris heathi MACFARLAND, 1905

Common

Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.
Vancouver Island to Laguna Beach.

Doridella steinbergae (LANCE, 1962) [see FRANZ, 1967]

Common. On bryozoan colonies on offshore kelp.
Morro Bay Docks.
San Juan Islands to Coronados Islands.

Doriopsilla ? *albopunctata* (COOPER, 1863)

Common

San Simeon, Cayucos, Hazard Canyon, Lion Rock, Avila,
Shell Beach.
Salt Point to Point Eugenia, Mexico.

Doto amyra ? MARCUS, 1961

Common

Morro Bay Docks, Hazard Canyon.
Monterey Bay to Santa Barbara.

* *Doto kya* MARCUS, 1961

Common

Cayucos, Morro Bay Docks, Hazard Canyon, Shell Beach.
Moss Beach to Shell Beach. (Moss Beach to Monterey
Bay).

Flabellinopsis iodinea (COOPER, 1862)

Frequent

Hazard Canyon, Avila (Port San Luis Wharf).
Vancouver Island to Coronados Islands.

Haminoea vesicula (GOULD, 1855)

Frequent

Morro Bay mud flats, Morro Bay Docks.
Alaska to Gulf of California.

Hancockia californica MACFARLAND, 1923

Rare

Hazard Canyon.
Dillon Beach to Punta Abreojos, Mexico.

Hermaeina smithi MARCUS, 1961

Frequent

Cayucos, Hazard Canyon, Shell Beach.
San Juan Islands to San Diego.

Hermisenda crassicornis (ESCHSCHOLTZ, 1831)

Common

Cayucos, Morro Bay Docks, Morro Bay mud flats, Hazard
Canyon, Lion Rock, Avila, Shell Beach.
Sitka, Alaska to Punta Eugenia, Mexico; Puertecitos,
Bahía de Los Angeles.

Hopkinsia rosacea MACFARLAND, 1905

Common

Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.
Coos Bay to Point Loma.

Laila cockerelli MACFARLAND, 1905

Rare

Lion Rock, Shell Beach.
Vancouver Island to Cape San Lucas.

Melibe leonina (GOULD, 1853)

Rare. On entangled offshore kelp fronds.
Morro Bay Docks.

Alaska to La Paz Bay, Mexico; Bahía de Los Angeles.

Navanax inermis (COOPER, 1862)

Frequent

Morro Bay mud flats.
Monterey Bay to Laguna Manuela, Mexico.

Okenia angelensis LANCE, 1966

Rare

Morro Bay Docks.
San Francisco Bay to Bahía de Los Angeles.

Onchidoris hystricina (BERGH, 1878)

Common

Morro Bay Docks, Hazard Canyon, Avila, Shell Beach.
Alaska to Point Loma.

Onchidoris spec.

Rare

Hazard Canyon, Lion Rock.

Phidiana pugnax LANCE, 1962

Common

Hazard Canyon, Avila, Shell Beach.
Monterey Bay to Coronados Islands

Phyllaplysia taylori (DALL, 1900)

Common. On *Zostera marina*.

Morro Bay mud flats.
San Juan Islands to San Diego Bay.

* *Pleurobranchus californicus denticulatus* MACFARLAND, 1966

Rare
Avila.
Monterey Bay to Avila. (Monterey Bay).

Polycera atra MACFARLAND, 1905

Common
Morro Bay Docks, Hazard Canyon, Shell Beach.
San Francisco Bay to Coronados Islands.

Polycera hedgpethi MARCUS, 1964

Frequent
Morro Bay Docks.
San Francisco Bay to Bahía de Los Angeles.

Precuthona divae MARCUS, 1961

Frequent
Hazard Canyon.
Monterey Bay to Santa Barbara.

Rostanga pulchra MACFARLAND, 1905

Common
San Simeon, Cayucos, Hazard Canyon, Lion Rock, Avila, Shell Beach.
Vancouver Island to Chile; Gulf of California.

Spurilla oliviae (MACFARLAND, 1966)

Frequent
San Simeon, Hazard Canyon, Lion Rock, Avila, Shell Beach.
Monterey Bay to Santa Barbara.

Stiliger fuscovittata LANCE, 1962

Frequent
Morro Bay Docks, Shell Beach.
San Juan Islands to San Diego; Bahía de Los Angeles.

* *Trapania velox* (COCKERELL, 1901)

Rare
Hazard Canyon, Avila.
Hazard Canyon to San Diego. (Santa Barbara to San Diego).

Trinchesia abronia (MACFARLAND, 1966)
[see ROLLER, this issue]

Rare
Shell Beach.
Monterey Bay to Pismo Beach.

Trinchesia albocrusta (MACFARLAND, 1966)
[see ROLLER, this issue]

Frequent
Morro Bay Docks, Hazard Canyon.
Monterey Bay to Santa Barbara.

* *Trinchesia flavovulta* (MACFARLAND, 1966)
[see ROLLER, this issue]

Rare
Shell Beach.
Monterey Bay to Shell Beach. (Monterey Bay).

Trinchesia lagunae (O'DONOGHUE, 1926)
[see ROLLER, this issue]

Frequent
Hazard Canyon, Lion Rock, Shell Beach.
Monterey Bay to Rosarito Beach, Baja California.

Triopha carpenteri (STEARNS, 1873)

Common
Hazard Canyon, Lion Rock, Shell Beach.
Vancouver Island to San Diego; Japan.

Triopha grandis MACFARLAND, 1905

Frequent
Morro Bay Docks, Avila.
Santa Cruz to Catalina Island.

Triopha maculata MACFARLAND, 1905

Common
Cayucos, Morro Bay Docks, Hazard Canyon, Lion Rock, Avila, Shell Beach.
Bodega Bay to San Diego.

Triopha spec. [same as in SPHON & LANCE, 1968]

Common
San Simeon, Cayucos, Morro Bay Docks, Hazard Canyon, Lion Rock, Avila, Shell Beach.

Tritonia exsulans BERGH, 1894

Rare. Subtidal from 180 feet.
Dredged from off Pismo Beach.
Vancouver Island to Baja California; Japan; Manatee Bay, Florida.

Tritonia festiva (STEARNS, 1873)

Frequent
San Simeon, Cayucos, Lion Rock, Avila, Shell Beach.
Vancouver Island to Coronados Islands.

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Monterey Bay to Santa Barbara.
- Aplysia vaccaria* WINKLER, 1955
Morro Bay to Gulf of California.
- Armina californica* (COOPER, 1862)
Vancouver Island to Panama
- Atagema quadrimaculata* COLLIER, 1963
Monterey Bay to San Diego.
- Chromodoris macfarlandi* (COCKERELL, 1902)
Monterey Bay to Coronados Islands.
- Dendronotus iris* COOPER, 1862
Vancouver Island to Coronados Islands.
- Elysia hedgpethi* MARCUS, 1961
San Juan Island to La Jolla; Bahía de Los Angeles.
- Fiona pinnata* ESCHSCHOLTZ, 1831
Pelagic.
- Hypselodoris californiensis* (BERGH, 1879)
Monterey Bay to Coronados Islands; Gulf of California.
- Hypselodoris porterae* (COCKERELL, 1902)
Monterey Bay to Cedros Island.
- Phylliroe bucephala* PERON & LESUEUR, 1810
Pelagic, worldwide.
- Platydoris macfarlandi* HANNA, 1951
Pismo Beach, subtidal at 516 feet.
- Thordisa bimaculata* LANCE, 1966
Carmel to Isla Natividad, Mexico.
- Tochuina tetraquetra* (PALLAS, 1788)
Alaska to Santa Barbara.
- Tylodina fungina* GABB, 1865
Cayucos to Todos Santos, Mexico; Guaymas, Mexico.

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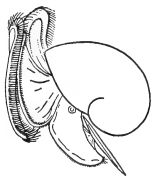
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A Note on the Range of *Gastropteron pacificum*

BY

HANS BERTSCH

Santa Barbara Museum of Natural History
Santa Barbara, California¹

(1 Map)

INTRODUCTION

Gastropteron pacificum BERGH, 1894, belongs to the order Cephalaspidea, a large opisthobranch group comprising 14 families and more than 150 genera and subgenera (TAYLOR & SOHL, 1962). Cephalaspideans are characterized by a cephalic shield, an expanded thickening of the dorsal surface of the head. This cephalic shield may possibly represent fused tentacle bases; in the cephalaspideans the tentacles are mostly absent, although the corners of the shield may be elongated into tentacle-like projections (HYMAN, 1967, p. 407). *Gastropteron* can form a temporary siphon by rolling the freely movable posterior margin of the cephalic shield into a tube (BERGH, 1894, p. 201).

When actively crawling, the general body form of the family Gastropteridae (containing the genera *Gastropteron* and *Sagaminopteron*) is an elongated cylindrical shape with paired lateral parapodia (continuous with the foot) turning up over the back, and with the prominent tail tapering back. By flapping the expanded parapodia the animal frequently swims through the water (BABA & TOKIOKA, 1965, p. 375, and HAEFELFINGER & KRESS, 1967). The radular formula of *Gastropteron* is $4\cdot6\cdot1\cdot0\cdot1\cdot4\cdot6$ (BABA & TOKIOKA, *loc. cit.*).

Detailed descriptions and illustrations of the egg masses and veligers of *Gastropteron pacificum* are given by HURST (1967). The adult shell (illustrated in KEEN, 1963, p. 17) is reduced, almost vestigial, and completely enclosed within the mantle. The ground color of the adult is a pale yellow ochre, mottled with clusters of small red spots. A thorough description of the adult anatomy is given by MACFARLAND, (1966, pp. 2-6; pl. 1).

TOKIOKA & BABA (1964) summarize the known ranges and main references of the 5 described species of *Gastro-*

pteron prior to their establishment of 4 new species from Japan.

GEOGRAPHICAL DISTRIBUTION

The published range of distribution of *Gastropteron pacificum* consists of a rather scattered series of localities along the Pacific coast of western North America. Along most of the coast it is listed as a presumed offshore species, especially in the approximately 350 miles of coast between Monterey Bay and Newport Bay.

An offshore, pelagic species, it is not encountered by the tidepool collector of opisthobranchs. The relative scarcity of *G. pacificum* is attested to by the majority of negative responses the author received upon inquiries to collectors asking if they had ever caught this species or if they knew of any specimens in museum or private collections. The present note correlates previously published accounts of the range of distribution of *G. pacificum* with more recent data obtained by James Lance and by the Santa Barbara Museum of Natural History from the collecting of Pat Brophy and Shane Anderson, substantiating its occurrence along the southern California coast.

With one exception, the literature prior to the publication of MACFARLAND's (1966) monograph on the opisthobranchs of the Pacific coast of North America gives the range of *Gastropteron pacificum* as extending from the Aleutian Islands, Alaska, to the Fuca Strait (south of Vancouver Island, British Columbia, Canada): BERGH, 1894; DALL, 1921; OLDROYD, 1927; KEEN, 1937; BURCH, 1945; LA ROCQUE, 1953; ABBOTT, 1954. SMITH & GORDON (1948), however, mention the occurrence of this cephalaspidean in Monterey Bay (dredged, rare).

More recently, STEINBERG (1963) indicates *Gastropteron pacificum* along with numerous other cephalaspideans, as occurring between San Diego and Vancouver Island,

¹ Permanent address: Franciscan School of Theology, 1712 Euclid Avenue, Berkeley, California 94709

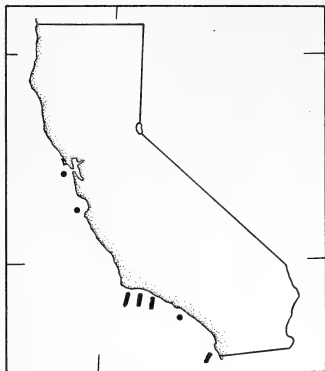


Figure 1

Western Coastline of California

The localities are, from north to south: off San Francisco, Monterey Bay, Gaviota, Santa Barbara, Ventura, Newport Bay, and Point Loma.

but does not include specific localities. MACFARLAND (1966) records this species from the following localities: off San Francisco; in Monterey Bay; Newport Bay; and along the west coast of Central America from the Gulf of California to the Galápagos Islands. Specimens collected in the vicinity of Friday Harbor, Washington, were used by HURST (1967) in her detailed study of opisthobranch veligers. SPHON & LANCE (1968) do not discuss the occurrence of any cephalaspideans in their checklist for Santa Barbara County.

Gaps in the range of *Gastropteron pacificum* occur between Fuca Strait and San Francisco, between Monterey and Newport Bays, and between Newport Bay and the Gulf of California. The following collecting data indicate the presence of *G. pacificum* in the latter two regions:

1. One specimen; in an otter trawl off Point Loma (San Diego), California, at approximately 100 fathoms. January 28, 1965. Collected by E. W. Fager of Scripps Institution of Oceanography and party [in the collection of James R. Lance].

2. One specimen; backwash of the filter system of the Undersea Gardens, Santa Barbara, California. January 24, 1968; collected by Shane Anderson, identified by Richard Lee (deposited in the collection of SBMNH, no. 25083).

3. Three specimens; Ventura, California, 85 fm. March 27, 1968. Collected by Pat Brophy, identified by Mrs. Jacque Rogers (one specimen in the collection of SBMNH no. 25084).

[The disposition of the remaining specimens, all collected by Pat Brophy, is unknown; data obtained through personal communication, J. R. Lance and P. Brophy.]

4. One specimen; Rincon, California (between Ventura and Santa Barbara), 50 fm. May 7, 1968.
5. One specimen; Santa Barbara, 105 fm. June 24, 1968.
6. One specimen; Gaviota, California, 106 fm. July 6, 1968.
7. Two specimens; Gaviota, California, 119 fm. July 29, 1968.
8. One specimen; Gaviota, California, 117 fm. July 30, 1968.
9. Two specimens; Santa Barbara, California, 130 fm. August 15, 1968.
10. Fourteen specimens; Santa Barbara, California, 12 miles offshore, 130 fm. August 16, 1968.
11. Ten specimens; Santa Barbara, California, 12 miles offshore, 123 fm. August 16, 1968.
12. Three specimens; Santa Barbara, California, 12 miles offshore, 134 fm. September 1, 1968.

The accompanying map indicates the subtidal localities along the California coast from which *Gastropteron pacificum* has been collected.

With increased offshore collecting, specimens of *Gastropteron pacificum* should be found throughout its entire range and, hopefully, more information will be gathered about the life history and distribution of this opisthobranch.

ACKNOWLEDGMENTS

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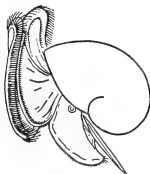
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An Immunological Study of Pelecypod Taxonomy

BY

LARKLYN FISHER

Department of Zoology, University of Illinois, Urbana, Illinois 61801¹

(3 Text figures)

INTRODUCTION

ANIMAL RELATIONSHIPS CAN BE studied in many different ways. Organisms are usually classified on the basis of similarities and differences in morphology, in physiology, in development, and in ancestry as shown by fossil remains. Another way that could be used to study relationship would be to consider the amount of difference in the types of substances present in the tissues, such as the proteins present in the muscles. This method was used in this experiment, in which muscle tissue from several species of clams was compared by immunological means.

Immunological methods have been used in the past to study taxonomy of vertebrates. The first extensive work of this sort was done by NUTTALL (1904) who showed that when blood sera from many species, including man, the great apes and the domestic cat and dog were used as antigens and tested with rabbit antisera, the reactions were greatest when the species from which the blood serum was taken was more closely related to the species from which the original antigen had been obtained for injection into the rabbit. In NUTTALL's study, increasing strength of the antibody-antigen reaction was found to follow a closer zoological relationship, and thus agree with standard taxonomy.

More recently, serological methods have been used in both plant and animal taxonomy, as in the work of FAIRBROTHERS & JOHNSON (1962) with systemics of the families Cornaceae (Dogwood) and Nyssaceae (Sour Gum); GOODMAN's (1962) immunological study of primate taxonomy; the serological comparison of 7 species of birds by DUWE (1962); the gel diffusion tests of ungulate taxonomy by MARABLE & GLENN (1962); and the investigation of turtle family relationships by FRAIR (1962).

The use of immunological techniques to study taxonomic relationships is based on the assumption that just as closely related clam species have more similarities of

gross morphology than do less closely related species, so do they also have more similarities in their tissue proteins. If a tissue, such as muscle, is ground up to break the cell walls and free the proteins, it can then be used as an antigen, that is, a substance to which antibodies can be produced. When this antigen is injected into a rabbit, the rabbit will make antibodies to the foreign proteins and these antibodies will appear in its blood serum. If this antiserum is mixed with the original antigen, the antibody and antigen molecules will attach to one another in great numbers and form a lattice, which is more dense than the surrounding fluid and will form a precipitate. This reaction between the antibodies and the proteins which make up their homologous antigen is quite specific². Thus, if there was a precipitate between antigen from the muscle of one clam and antiserum made against the muscle tissue of another clam, it would show that the two had at least one protein in common. If two such lines of precipitate met and merged, it would show that they were reactions to a single protein, present in both subjects. If they did not merge, however, this would demonstrate that while muscle tissue from each species did have a protein in common with the original antigen to which the antiserum was made, it was not the same protein; therefore each of these two species of clams had one protein in its muscle that the other one did not have, thereby indicating a more distant taxonomic relationship. These were the principles that were used in the present experiment, to examine the amount of relationship shown among several different species of clams.

METHODS

Seven species of clams were used in this experiment, 6 of which occur in the fresh water streams of Illinois, and one that is marine, from the coast of the State of Washington. The fresh water species were:

¹ Present address: 5421 60th Str. N.E., Seattle, Washington 98105

² see BOYD, 1966, pp. 370-371

SPHAERIIDAE

Sphaerium striatinum (LAMARCK, 1818)

UNIONIDAE

Unioninae

Quadrula pustulosa (LEA, 1834)

Anodontinae

Anodonta grandis SAY, 1829

Lasmigona complanata (BARNES, 1823)

Lampsilinae

Lampsilis ventricosa (BARNES, 1823)

Actinonais carinata (BARNES, 1823)

The marine clam was:

VENERIDAE

Saxidomus nuttalli CONRAD, 1837.

The antigen to be injected was obtained from 3 species, *Lampsilis ventricosa*, *Quadrula pustulosa*, and *Lasmigona complanata*. The retractor and adductor muscles were removed, cut into fine pieces, extracted in saline solution, frozen and thawed several times and the same samples were then ground in a hand grinder. The protein concentrations of the antigen preparations were determined by the biuret method, using a colorimeter. Each antigen was injected several times (see antigen schedule below) into 2 rabbits. Injections were made intramuscularly, with the dose divided into 4 injections, one in the proximal part of each limb. At the time of the injections, 15 to 20 cc were bled from an ear of each rabbit, the clot removed and the serum centrifuged to prevent hemolysis. Pre-immunization (control) bleedings were taken from each rabbit before the first injection. The schedule of bleedings, antigen injections and their concentrations is given below.

ANTIGEN SCHEDULE

Antigens from *Quadrula pustulosa*:

1. Antigen concentration - 1.68 mg/ml protein
Injected - day one: 10 ml antigen for 16.8 mg protein and 5ml Freund's complete adjuvant, thoroughly mixed, into rabbits one and two.
2. Antigen concentration - 0.67 mg/ml protein
Injected - day nine: 7.5 ml antigen for 5 mg protein and 5 ml Freund's complete adjuvant into the same 2 rabbits.
3. Antigen concentration - 0.60 mg/ml protein
Injected - day eighteen: 14 ml antigen for 8.4 mg protein and 6 ml Freund's complete adjuvant into rabbit number one only.

Antigens from *Lasmigona complanata*:

1. Antigen concentration - 1.0 mg/ml protein
Injected - day three: 10 ml antigen for 10 mg protein

and 10 ml Freund's complete adjuvant into rabbits three and four.

This was the only injection of *Lasmigona complanata* material as no more specimens of this species could be obtained.

Antigens from *Lampsilis ventricosa*:

1. Antigen concentration - 1.68 mg/ml protein
Injected - day one: 11.5 ml for 18.3 mg protein and 5.5 ml Freund's complete adjuvant into rabbits five and six.
2. Antigen concentration - 0.4 mg/ml protein
Injected - day nine: 7 ml for 2.8 mg protein each into the same two rabbits.

The rabbits were bled on days one, nine, eighteen, and thirty-three even when they were not injected.

Diffusion plates were prepared by pouring a 1% solution of agar agar no. 3 (Oxoid Co.) onto 16 plates, and cutting wells $\frac{1}{4}$ inch in diameter and $\frac{3}{8}$ inch apart in substrate $\frac{3}{8}$ inch deep, following the Ouchterlony procedure. Antigens and antisera were placed undiluted in the wells of the plates shown in the diagrams below. The results with the first group of plates (Text figure 1) indicated that dilution of the antisera would improve the readings. Therefore each antiserum was diluted 1:1; 1:4; 1:8; 1:16; 1:32; and 1:64 and tested against its homologous antigen, except for the antisera to *Lasmigona complanata* as no more antigen from this species was available. From the results of these tests, the antisera were diluted 1:6 in the second group of plates, except that from rabbit number six, which was diluted 1:1. All of the plates were observed after 1, 3 and 5 days of refrigeration and the results were recorded.

RESULTS

The patterns of precipitation on the plates are shown on the diagrams below. These are the patterns on the fifth day, when the plates seem to have attained their full development.

Preimmunization (control) bleedings: the absence of precipitation indicated that the rabbits had no antibodies to the clam proteins at the beginning of the experiment.

DISCUSSION AND CONCLUSIONS

The results indicated that each of the clam species used in this experiment was more closely related to some of the remaining 6 than to others. These relationships agreed in the main with conventional taxonomy but showed that more distantly related groups may have a good deal more in common than one might expect. The amount the spe-

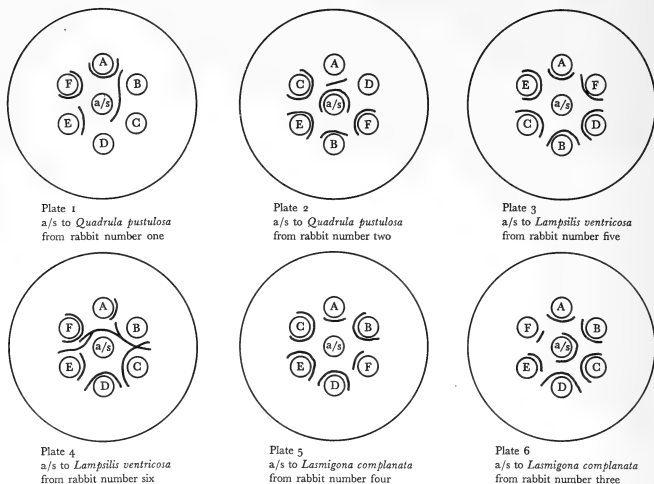


Figure 1

cies share is amplified by the fact that these animals are not closely related to rabbits. According to LANDSTEINER (1936) antibody formation is directed against those features that are foreign to the animal forming the antibody; thus much of a rabbit's antibody forming capacity would be directed against the major structural features not occurring in rabbits, but common to all clam proteins. This would also mean that only part of the antibodies would distinguish the relatively minor species differences among the clam proteins. The diagram (Figure 3) shows the similarities of muscle proteins that were found in this experiment. Each line represents one positive reaction, and if 2 or more antibody-antigen systems precipitated to-

gether, it would represent more than one substance in common in their muscle tissues. It must be noted, however, that the gel diffusion tests would not have detected differences or similarities among clam proteins that are also present in rabbits, as the rabbits would not have recognized them as foreign and so would not have produced antibodies against them.

Each antigen could have shown reaction 5 or 6 times, had all reactions been positive. The number of possible positive reactions for each species, the number of those that were prevented because of precipitation too close to the well of antigen and the number of reactions that were actually positive, are shown in Table 1.

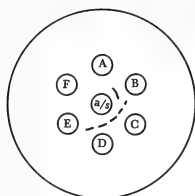


Plate 1
a/s to *Lamprolis ventricosa*
from rabbit number six

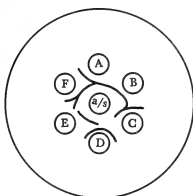


Plate 2
a/s to *Lamprolis ventricosa*
from rabbit number six

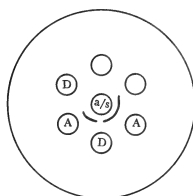


Plate 3
a/s to *Lamprolis ventricosa*
from rabbit number six

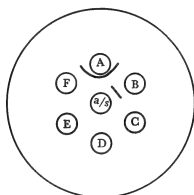


Plate 4
a/s to *Lasmigona complanata*
from rabbit number four

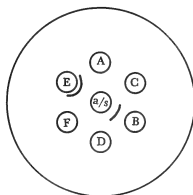


Plate 5
a/s to *Lamprolis ventricosa*
from rabbit number five

Figure 2

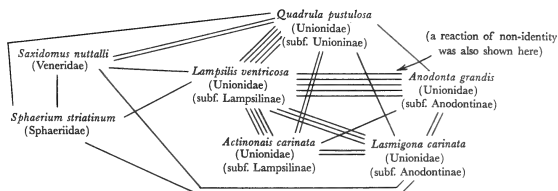


Figure 3

Similarities Shown Among Muscle Proteins

Table 1
Percentage of Positive Tests

Species	Percentage Positive	Possibilities in Experiment	Number Prevented	Valid Possibilities	Positive Tests
<i>Lampsilis ventricosa</i>	100%	6	0	6	6
<i>Lasmigona complanata</i>	100%	6	0	6	6
<i>Quadrula pustulosa</i>	100%	6	0	6	6
<i>Actinonaias carinata</i>	80%	6	1	5	4
<i>Saxidomus nuttalli</i>	80%	6	1	5	4
<i>Anodonta grandis</i>	67%	6	0	6	4
<i>Sphaerium striatinum</i>	67%	6	0	6	4

The species at the top of this table showed a positive reaction at least once with each species tested against them, while those in the lower part of the table showed less and less relationship with the other species.

The results of this experiment might have shown more if several other species of bivalves could also have been used, and if the antisera had been diluted for the first group before being placed in the wells so that precipitation would have taken place farther from the wells of antigen. However, the results showed two things: first, that groups considered more distantly related do have a good deal of similarity in their muscle proteins, and, secondly, that classification by common factors in muscle proteins agrees substantially with the classification based on morphology, physiology and development.

SUMMARY

The amount of relationship among 7 species of bivalves was compared by immunological methods, using their muscle tissue as the antigen and testing for similarity of muscle proteins of the different species using the Ouchterlony technique. Six of the species were from fresh water, representing 2 families and within one of these 3 subfamilies. The seventh species was marine from the Pacific

coast. The results showed 2 things: bivalves more distantly related to one another have a good deal of similarity in their muscle proteins, and that classification of pelecypods by common factors in muscle proteins agrees substantially with that based on morphology, physiology and development.

ACKNOWLEDGMENT

I would like to thank Dr. Nelda E. Alger for her constructive criticism of the manuscript.

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NOTES & NEWS

An Overlooked Subgenus and Species
from Panama

BY

A. MYRA KEEN

Department of Geology, Stanford University
Stanford, California 94305

Trichotropis gouldii A. ADAMS, 1857 was described in the Proceedings of the Zoological Society of London for 1856 (p. 389, published January 10, 1857). The Latin description, freely translated, is as follows:

Shell ovate-fusiform, very slightly umbilicate, white, thin; spire high; with seven convex whorls having raised lirae, the spire beautifully cancellate and the interspaces striate with thin longitudinal lamellae; aperture oval, produced anteriorly, canal obsolete; outer lip smooth, rounded, anteriorly slightly reflected, inner lip with simple sharp edge.

Length, $1\frac{1}{2}$ poll. [37 mm]. Hab. Chiriqui, Veragua [W. Panama].

ADAMS surmised that the shell might have had a periostracum when alive, and he noted that "it differs from the typical genus in the canal of the aperture being almost obsolete."

In 1861 HENRY ADAMS (Proc. Zool. Soc. London, 1861, p. 272) proposed the subgenus *Alora*, with *Trichotropis gouldii* the sole species. Since then it has dropped from notice.

Because the shell ADAMS described had been in the Cuming collection, I searched for it in the collection of the British Museum (Natural History) when I was there in 1964 and 1965 and again in 1967 but without success. If the shell is still in the Museum's collection, it has been mislabelled and the original notations obscured or lost.

Leafing through the illustrations of known Panamic gastropods for a possible identification, I can come up with only one form from Panama that meets all the requirements of ADAMS' original description. This is *Recluzia insignis* PILSBRY & LOWE, 1932. The major difference is in size, for the PILSBRY & LOWE holotype is stated to be only 15 mm high. They even mention the thin

periostracum that was predicted by ADAMS. Therefore, I suspect that the PILSBRY & LOWE species is going to prove to be a synonym, but even if it can be retained, it should be transferred from *Recluzia*, a genus in which the shells are normally smooth, to *Alora*. Also, *Alora* should be divorced from *Trichotropis* (a North Pacific genus) and elevated to generic rank, with *A. gouldii* (A. ADAMS, 1857) as type by monotypy. Sculpture and form of the shell would suggest removal of the genus from Janthinidae and transfer to Epitonidae, where it might find a place somewhere near *Scalina*.

Laternula Living on the Pacific Coast?

BY

A. MYRA KEEN

Department of Geology, Stanford University
Stanford, California 94305

In 1963 MISS CATHERINE DUNLOP, who was identifying mollusks for an ecologic project being undertaken by Portland State College students under Dr. John MacNab, sent several small clams for determination. One lot proved to be *Laternula*, a genus not native to the West Coast. The specimens had been taken in Coos Bay, Oregon, about 150 feet from shore. There were two specimens, both somewhat broken but with valves intact, one clearly showing a lithodesma on the hinge.

Mr. Keith B. Macdonald, working in marsh channels of Coos Bay in 1966, submitted two more specimens of *Laternula* for identification. These also seem to have been alive when taken, though the soft parts were missing by the time I saw them. The periostracum was fresh, and one valve showed a fragment of the lithodesma. These specimens were slightly larger than the earlier two but smaller than most adult *Laternula*. Comparison of the two lots and study of the literature on Japanese *Laternula* (the most likely source of importation), suggests that the species probably is *Laternula* (*Laternula*) *limicola* (REEVE, 1863), a form that occurs on mud flats in central and northern Japan. The fact that two lots were taken in Oregon three years apart would imply that this Japanese bivalve may be becoming established in American waters. (Order Anomalodesmata; Superfamily Pandoracea).

Donation by San Diego Shell Club

The Veliger Operating Fund has received another generous contribution from the San Diego Shell Club.

These donations are used, in accordance with the wishes of the donors, to assist in paying for plates of authors who are not in a position to carry the full burden themselves, either because of foreign exchange restrictions by their authorities or because of lack of access to the needed funds. While it is the aim of The Veliger eventually to absorb all expenses of publishing the journal, the financial position of the California Malacozoological Society is such that this goal is not yet achieved - in fact, far from it. It is, therefore, an especially welcome event and we, on our own behalf as well as that of some author(s) who will benefit from it, express our sincere appreciation of this continued support.

The Editor.

Important Notices

If the address sheet of this issue is PINK, it is to indicate that your dues remittance had not arrived at the time the mailing was prepared. We wish to take this opportunity to remind our Members that a reinstatement fee of one dollar becomes due if membership renewals have not been received by C. M. S., Inc. by April 15, 1969.

Sexual Dimorphism in *Tegula funebris*

BY

PETER W. FRANK

Department of Biology, University of Oregon
Eugene, Oregon 97403

DURING A STUDY of behavioral and distributional differences between the sexes of *Tegula funebris* (A. ADAMS, 1855), a method allowing the animals to be sexed without killing them has been discovered. The crawling surface of the foot is cream- to light brown-colored. The chemical basis of the pigmentation is unknown; the color suggests a carotenoid. If one separates the lightest from the

darkest individuals, those with the lightest undersides are virtually consistently males, the dark ones females (see Table 1). Since there are a number of intermediate individuals, approximately the last quarter of any given sample can not be separated into sexes by this means. Moreover, the difference in pigmentation does not show up in snails less than about 1.5 cm wide, i. e., several millimeters larger than the size at which sex may be distinguished from the color of the gonad, once the shell is broken.

This research is supported by grant GB 5032 of the National Science Foundation.

Table 1

Number of *Tegula funebris* with dark and light crawling surfaces compared with respect to sex. Data obtained in August 1968 from animals collected at Cape Arago, Oregon

Surface of Foot	Sample 1		Sample 2	
	♂	♀	♂	♀
Dark	4	48	3	19
Light	27	6	20	0
Intermediate	16	9	5	4

Spawning Notes, III. - *Strombina maculosa*

BY

FAY H. WOLFSON

San Diego Natural History Museum,
San Diego, California 92115

(3 Text figures)

COMMUNAL SPAWNING by *Strombina maculosa* (SOWERBY, 1832) was observed by Glenn and Martha Vargas at Bahía de los Angeles, Baja California during the extreme low tides of 26 and 27 June 1968. Large numbers of individuals, in aggregations, were depositing egg capsules on small stones, in mussel valves and on other empty shells. An appreciably smaller number was observed spawning two weeks later during the lowest tides of the next spring-tide cycle.

The capsules are deposited in rows (Figure 1); on the stone collected there are 2 rows of 16 and a third of 12.



Figure 1

Strombina maculosa (SOWERBY, 1832)
Egg capsules on stone

The capsules are separated by a distance of at least 2 mm except at the base, where the flaring membranes attaching them to the substrate are contiguous, but not connected.

Viewed microscopically, the puckered and opaque appearance of the capsules is seen to result from an intricate pattern of irregularly shaped "facets" into which the entire transparent surface is divided.

The capsules average 9.1 mm in maximum height, 7.2 mm in maximum width. Average width of the top ridge (Figure 3) is 0.93 mm, of the side ridges, 0.69 mm. There is no sign of an inner membrane or of a special structure to serve as exit at hatching time. The few veligers (less than 100 per capsule) are scattered irregularly through-

out (Figure 2). They average 0.187 mm in greatest diameter.

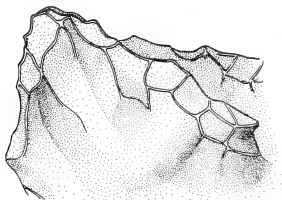


Figure 3

Strombina maculosa (SOWERBY, 1832)
Detail of top of capsule, with a few of the "facets" of the top and side ridges shown

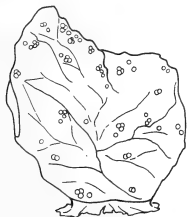


Figure 2

Strombina maculosa (SOWERBY, 1832)
A single capsule

Spawning Notes, IV.

Cerithium stercusmuscarum

BY

FAY H. WOLFSON

San Diego Natural History Museum,
San Diego, California 92115

(2 Text figures)

THE SPAWN OF *Cerithium stercusmuscarum* VALENCIENNES, 1833 is comparatively simple. It resembles that of the Bermuda species, *C. ferrugineum* SAY, in that spawning occurs near the high tide line and the eggs are encased in a gelatinous matrix within a thin-walled tube, but differs in the form assumed by the spawn: that of *C. ferrugineum* resulting in a loose coil (LEBOUR, 1944), that of *C. stercusmuscarum* being laid down in loops (Figure 1).

Several hundred *Cerithium stercusmuscarum* were congregated at the edge of a tidal lagoon at La Gringa, Bahía de los Angeles, Baja California on 23 and 31 August 1968. Water temperature was 31° C. I found the pale yellow spawn and from 1 to 12 individuals in the process



Figure 1

Cerithium stercusmuscarum VALENCIENNES, 1833
The egg ribbon

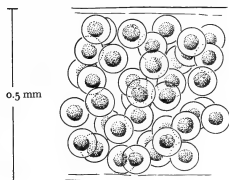


Figure 2

Cerithium stercusmuscarum VALENCIENNES, 1833
A segment of the ribbon

of depositing more on the underside of almost every rock in an area of approximately 12 m² at the water's edge.

The loops vary in orientation, height and spacing. Although one surface of the ribbon is usually continuously attached to the substrate, occasional loops stand free. A small segment of a ribbon that covered 32 cm² is shown in Figure 1. The tube is slightly flattened and measures 0.25 mm × 0.5 mm in cross-section. The eggs, averaging 0.1 mm in diameter, are very numerous, 50 or more being packed into a ½ mm segment of the long ribbon.

The figures were drawn by Anne Acevedo of the San Diego Natural History Museum.

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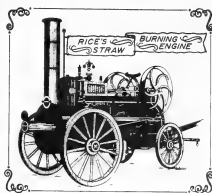
Manuscripts received up to February 14 each year will be considered for publication in our July issue; May 14 is the deadline for the October issue, August 14 for the January issue and November 14 for the April issue. For very short papers of less than 500 words (including title, etc.) the deadlines are one month later than those given above, provided that these short notes are important enough to warrant preferential treatment. It is, however, understood that submission of a manuscript before the dates indicated is not a guarantee of acceptance.

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We must emphasize that these charges cover only our actual expenses and do not include compensation for the extra work involved in re-packing and re-mailing returned copies.

Because of the changed rules affecting second class mail matter, we will no longer be able to include the customary reminders in our January issue, nor can we attach any flyers to our journal henceforth. We shall, from now on, print a statement when dues-renewal time has arrived or announcements regarding special publications in our NOTES & NEWS column.

BOOKS, PERIODICALS, PAMPHLETS

Die europäischen Meeres-Gehäuseschnecken (Prosobranchia)

vom Eismeer bis Kapverden und Mittelmeer

by Dr. FRITZ NORDSIECK. 1968. viii+273 pp.; 1200 line drawings on 31 plates; 16 color pictures on 4 plates. Hardcover, 48.- German marks; Gustav Fischer, publ., Stuttgart, West Germany.

This book will be a most welcome addition to the malacological library of museums as well as collectors in general. Although the scope of the work is limited to shell-bearing prosobranchs of the European seas (including the Mediterranean), and although it excludes the pyramidellids (as these animals are now generally believed to be opisthobranchs), it still covers 1220 species and 180 subspecies and includes the descriptions of 5 new species and 7 new subspecies. While the worker who is not very conversant with the German language may have some difficulties with the text, he will find the approximately 1200 line drawings, illustrating almost every species, of great help.

The treatment of the species is thorough and consistent. Not only are all major taxa succinctly defined (i. e., super-families, families, subfamilies and genera, but in the latter case the type species is given, as well. The treatment of the species starts with the currently valid name, followed by synonyms, if any. Size indications and distribution data precede the diagnosis of the species. Color indication (for the animal), anatomical and radular characteristics are mentioned, where known or references to generally available literature are listed.

In the opinion of this reviewer the unusually large store of important information contained in a very compressed form through the liberal use of abbreviations could be made more easily available to the non-German worker if a list of all abbreviations were appended, or, at least of some of the less commonly encountered ones, such as "idR." which stands for "in der Regel" or, in English, "as a rule".

RS

The Zoological Taxa of William Healey Dall

by KENNETH J. BOSS, JOSEPH ROSEWATER & FLORENCE A. RUHOFF. U. S. National Museum Bulletin 287: 427 pp., 1968. Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 20402. Price: \$2.50, paper cover.

William Healey Dall described and named a total of 5427 taxa. Of these 5302 belong to the mollusks.

Many of Dall's papers were published in periodicals that are now either very rare or difficult to find. The authors have made a careful compilation of all names created by Dall, omitting only the suprageneric taxa for very good reasons.

In their introduction the authors stress that the list was compiled with a meticulous avoidance of rendering decisions, or even suggestions, as to the proper assignment of the various taxa, leaving this task for the specialist to do when they review one higher taxon or another.

Of special value to the taxonomist is the account of Dall's early work in which he indulged in practices that have caused much confusion. It might be stressed here, however, that Dall apparently adhered meticulously to the Rules of the International Commission on Zoological Nomenclature after the Rules were established.

The alphabetical arrangement of the taxa created by Dall make this book easy to use. It is not possible to overestimate the value of this work and it is no exaggeration when we say that it should be in the library of every serious student of malacology. The cost of the book can be this low only because it is produced by a non-profit making organization, the United States Government.

RS

The Shell.

Five Hundred Million Years of Inspired Design
by HUGH and MARGUERITE STIX, and R. TUCKER ABBOTT.
Harry N. Abrams, Inc. \$25.00; approx. 200 pp.; illus.

This is a gorgeous art book that serves to present with a dramatic layout and design the beautiful diversity of shell characters possessed by the world of living mollusks. The 203 illustrations, including 82 hand-tipped plates in full color, are the creative photographic work of H. Landshoff. Dr. R. T. Abbott, the well known malacologist, collaborated with The Stixs, who are New York shell dealers, to provide a scientifically accurate commentary. This attractive, large volume is not only oriented to the general reader of natural history, but it will be especially welcomed by students of art and design in nature, and by the legion of avid shell collectors.

W. K. Emerson



The Helmet Shells of the World (Cassidae).

Part I. — R. TUCKER ABBOTT. Indo-Pacific Mollusca, vol. 2, no. 9, 202 pp., 187 pls. Publ. by the Department of Mollusks, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania 19103. \$14.75.

ALPHA taxonomy concerns itself with the characterization and naming of species and is often eclipsed by the more spectacular results of BETA and GAMMA taxonomy. But perhaps there should be an OMEGA taxonomy, an all-there-is-to-know level of the study of organic diversity. ABBOTT's paper is the OMEGA approach to a family of higher prosobranch gastropods to which have been applied over a thousand names but which constitute about 60 living species. Part I of this monograph considers the genera *Cassis*, *Cypraeacassis*, *Phalium*, and *Casmaria*. The world-wide coverage of the living species and the inclusive treatment of the many fossil species constitute an outstanding contribution to malacology.

The most interesting aspect of this paper is its illustration of the dynamics of evolution. In contrast to results of typological approaches of the past, this study reveals the probabilistic nature of biological phenomena and exposes species as natural entities in different stages of the evolutionary process. Species possess both spatial and temporal dimensions. Recent populations are the survivors of the past and some have stabilized a genetic system which permits little phenotypic divergence while others are spectacularly variable.

The results of this paper show:

1. polytypic species of a wide distribution whose nearly indistinguishable subspecies are allopatrically separated by thousands of miles (*Cypraeacassis testiculus testiculus* and *C. t. senegalica*; *Phalium granulatum*, *P. g. centriquadratum*, and *P. g. undulatum*);
2. species in the process of forming geographic isolates (incipient subspecies) with the ultimate prospect of genetic distinction and speciation (*Phalium areola*);
3. polytypic species whose rapid divergence has resulted in a fragmentation into 'parapatric' subspecies with virtually little isolation (*Casmaria erinaceus*);
4. two species of *Xenophalium* with a broad spectrum of ecophenotypic and intrademe variation coupled with the possibility of introgressive hybridization.

In general, the papers are excellent. The maps are of value for the immediate assessment of distributional data,

but they should be referred to in the text under the respective species. The information included on depth distribution, bottom type preference and probable feeding habits is important.

This work is uneven in the treatment accorded various taxa. Cenozoic European species and subspecies of the *mamillaris* (p. 55) and *rondeleti* (p. 97) complexes are discussed more thoroughly than some fossil *Phalium* (p. 152) and *Galeodosconsia* (p. 123) where the species are only listed. The use of a key to the species of *Phalium s. s.*, but not to those of other genera and subgenera is unfortunate. The term '*forma*' has no biological or evolutionary significance, and its usage in a modern taxonomic study is deplorable.

Type-information is now generally included in the synonymy; it presents mistakes of omission: where is the type of *menkrawitense* BEETS?; the syntypes of *Cassis pfeiferi* are in the Madrid museum according to the caption to plate 111, but they are not mentioned in the paragraph on types of *P. bisulcatum*, with which *pfeiferi* is synonymous.

A more trenchant discussion of the genera, their phylogenetic relationships and distinctiveness plus a diagnostic key to the Recent genera and subgenera should be included in the second portion of this monograph as should an expanded bibliography which includes all the papers cited in the text.

The reviewer wonders how the same author who recognizes the great variation in *Phalium bisulcatum* and syntactically treats the *Phalium coronadoi-wyvillei-pilsbryi* species complex can then describe a new species, *P. kurodai* (p. 105, pl. 87) which differs from the ecologically and geographically sympatric *P. carnosum* (p. 104, pl. 86) by a mere number of knobs.

An important error in type-setting occurs on p. 200. The remainder of the paragraph on **Types and Records** for *Casmaria ponderosa nipponensis* is found on p. 201, bottom of first column under *C. ponderosa perryi*. And the subspecies discussed under *ponderosa* are placed in the polytypic species *erinaceus* in the captions on plate 14.

Dr. Abbott is to be congratulated for a substantive contribution to the malacological literature. His study has shown that to obtain a modern systematic revision of a cosmopolitan family, research must be done on a world-wide basis and not be constricted by the parochialism which has characterized much systematic work.

Kenneth J. Boss

Oceans

a monthly magazine, published by Jack C. Reynolds.

Subscription \$9.- from Oceans Magazine, P. O. Box 1820, La Jolla, California 92037.

This new magazine, started in January 1969, is devoted to the lore of the oceans. It brings in popular language and with numerous black-and-white and excellent color illustrations articles on many topics. As may be expected, the emphasis is not on mollusks, although this group of marine creatures is by no means neglected.

An interesting feature of the magazine is the section entitled "Sea Squirts" - written primarily for the young reader, although of interest also to the layman in general. Another valuable section is the glossary appended to each issue in which scientifically accurate definitions of the technical terms used in the articles are given.

Advertising is restricted to non-text pages, a commendable arrangement. It is to be hoped that this will not be changed when increased circulation makes the magazine an attractive advertising medium. It would be deplorable to have an interesting account of salmon biology broken up by sales pitches for diving gear or underwater photography. As it is now, the magazine can be recommended

to any one interested in any of the many thousands of problems connected with the oceans.

RS

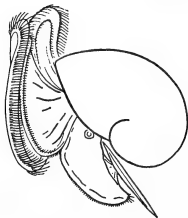
A Checklist of the Marine Gastropods from the Puget Sound Region

by THOMAS RICE. Of Sea and Shore, P. O. Box 33, Port Gamble, Washington 98364. Approximately 170 pp.; 4 maps with list of collecting stations; frontispiece.

This mimeographed checklist is divided into an alphabetical list of species, occupying 138 pages; a bibliography of 9 pages; an index of 9 pages and a systematic list of 7 pages. Under each species in the first part of the list are given references, followed by indications of the range of the species; in most instances the type locality is also mentioned and usually collecting data in the Puget Sound area complete the entry. Where the author is aware of synonyms, he is careful to include them.

A possible flaw in the list is the fact that, as stated in the introduction, "Not all specimens have been checked for the validity of the record, but those interested might contact those collectors listed in the "Collecting data" sections in reference to particular species."

RS



THE VELIGER is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or other taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, may be published in the column "NOTES and NEWS"; in this column will also appear notices of meetings of regional, national and international malacological organizations, such as A. M. U., U. M. E., W. S. M., etc., as well as news items which are deemed of interest to our Members and subscribers in general. Articles on "METHODS and TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, and PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

Manuscripts should be typed in final form on a high grade white paper, not exceeding 8½" by 11", at least double spaced and accompanied by a clear carbon or photo copy. A pamphlet with detailed suggestions for preparing manuscripts intended for publication in THE VELIGER is available to authors upon request. A self-addressed envelope, sufficiently large to accommodate the pamphlet (which measures 5½" by 8½"), with double first class postage, should be sent with the request to the Editor.

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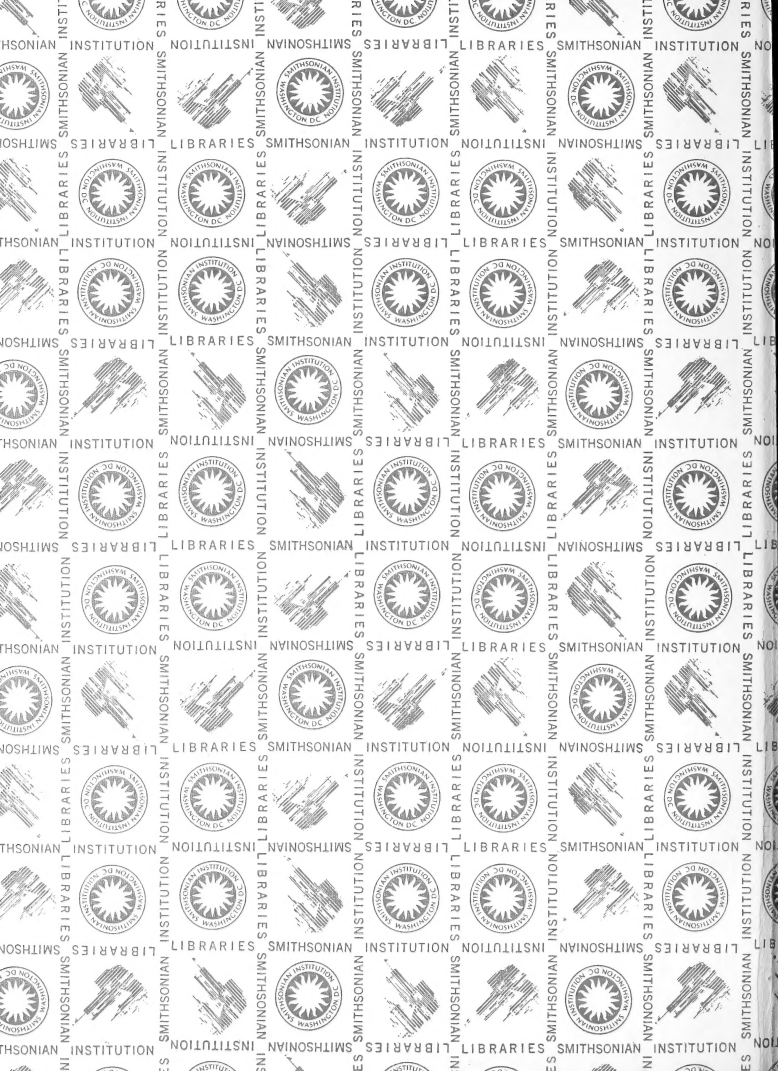
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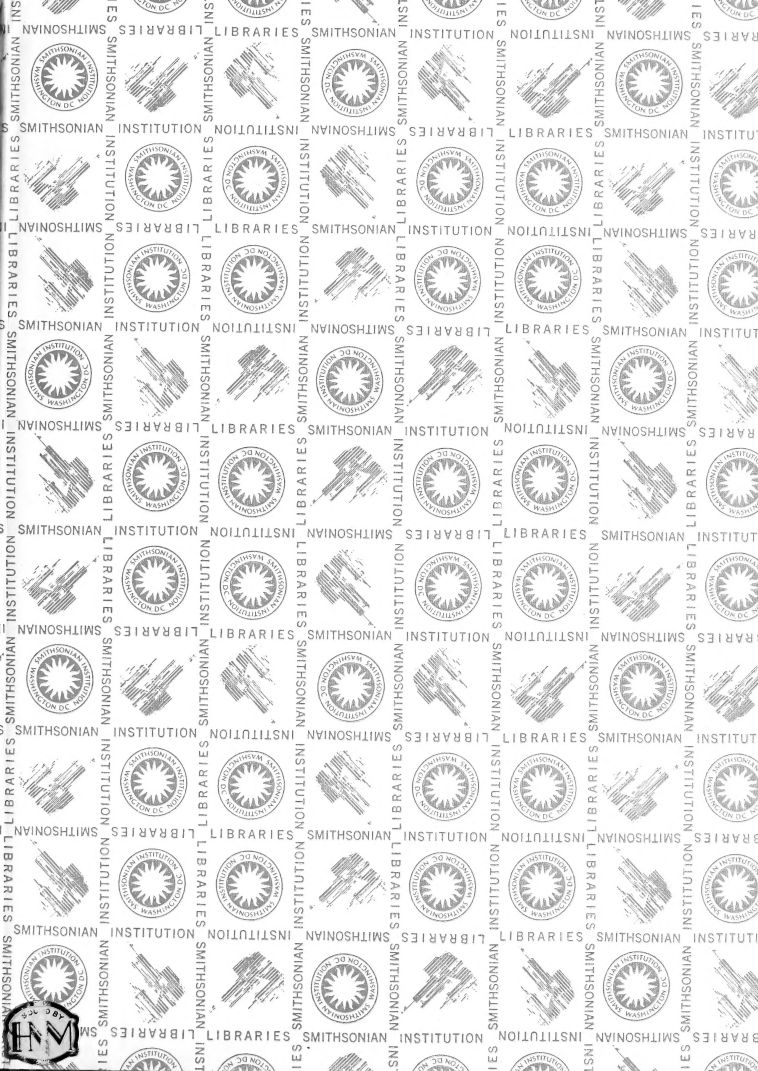
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